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ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS F/G 11/2  
INVESTIGATION OF PERFORMANCE OF CONCRETE AND CONCRETING MATERIA--ETC(U)  
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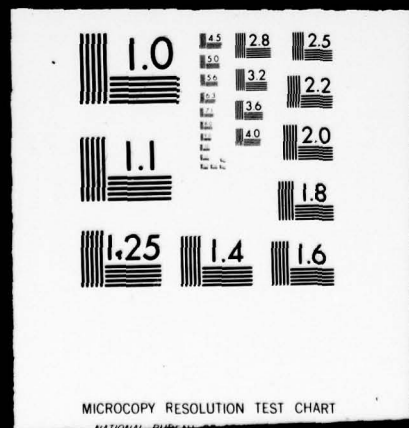
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**INVESTIGATION OF PERFORMANCE OF  
CONCRETE AND CONCRETING MATERIALS  
EXPOSED TO NATURAL WEATHERING**

**Volume I**

**ACTIVE INVESTIGATIONS**



**TECHNICAL REPORT NO. 6-553**

**June 1960**

**AD-A075359**

**U. S. Army Engineer Waterways Experiment Station  
CORPS OF ENGINEERS**

**Vicksburg, Mississippi**

**ARMY-MRC VICKSBURG, MISS.**

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PURPOSES

(Issued August 1977)

INVESTIGATION OF PERFORMANCE OF CONCRETE AND CONCRETING

MATERIALS EXPOSED TO NATURAL WEATHERING

TECHNICAL REPORT NO. 6-553

June 1960

Supplements, Corrections, and Revisions  
Distribution No. 14\*

August 1977

VOLUME 1

ACTIVE INVESTIGATIONS

Item	Part	Section	Supplement, Correction, or Revision
11		Preface	Revised pp iii, iv, and new p v
12		Contents	New pp vii and viii
13		Conversion Factors	New p ix
14		Summary	New p xi
15	I		Revised Table 1 and reprinted Table 2
16	II	1	Revised sheet 3 of Table 1-TC-A
17	II	2	Revised sheet 8, and new sheets 9 and 10 of Table 1-TC-B
18	II	3	Revised sheet 2 of Table 1-SF
19	II	4	New sheet 2 of Table 1-CRMI-PB
20	II	5	Revised Table 1-CERL-FC (1 page)
21	II	6	Revised sheets 2 and 3 of Table 2-PR; revised sheet 2 of Table 5-PR; revised sheet 3 of Table 6-PR

\* TR 6-553 was issued in June 1960. Distributions of Supplements, Corrections, and Revisions are issued each year. This distribution, No. 14, brings the report up to date as of July 1977.

(Issued August 1977)

<u>Item</u>	<u>Part</u>	<u>Section</u>	<u>Supplement, Correction, or Revision</u>
<del>12</del>	II	7	Revised Table 1-WES-FC (1 page)
<del>13</del>	II	8	Revised sheet 5 of Table 1-CRMI-PD; revised sheet 3 and new sheet 4 of Table 2-CRMI-PD
<del>14</del>	II	9	Revised sheet 2 of Table 1-PQ
<del>15</del>	II	10	Revised sheet 2 of Table 1-SC; revised Table 2-SC (1 page)
<del>16</del>	II	11	Revised sheets 2, 3, and 4 of Table 1-BFS
<del>17</del>	II	12	Revised Table 1-SSFE (1 page)
<del>18</del>	II	13	Revised Table 1-TP (1 page)
<del>19</del>	II	14	Revised Table 1-4.5A (1 page)
<del>20</del>	II	15	A new item including Key (1 page), text (1 page), Tables 1 (1 page), 2 (2 pages), 3 (1 page), and 1-SIC (1 page)
<del>21</del>	II	16	A new item including Key (1 page), text (1 page), and Table 1-RCC (1 page)
<del>22</del>	II	17	Revised sheets 9, 10, 11, and 12 of Table 1-LTS
<del>23</del>	II	18	A new item including Key (1 page), text (1 page), Table 1, and Table 1-NED (1 page each)
<del>24</del>	II	22	Revised Table 1-MM (1 page)
<del>25</del>	II	25	Revised sheet 6 of Table 1-CRA
<del>26</del>	II	26	Revised Table 1-OD (1 page)
<del>27</del>	II	27	Revised sheet 2 of Tables 1-KCD and 2-KCD; revised Tables 3-KCD, 4-KCD, 5-KCD, 6-KCD, and 7-KCD (1 page each)
<del>28</del>	II	28	Revised Table 1-ED (1 page)
<del>29</del>	II	34	Revised Table 1-MCP (1 page)
<del>30</del>	II	35	Revised Tables 1-QA and 2-QA (1 page each)
<del>31</del>	II	37	Revised sheet 3 of Table 1-CAP
<del>32</del>	II	38	Revised sheet 2 of Table 1-MAWC
<del>33</del>	II	39	New sheet 3 of Table 1-CT
<del>34</del>	II	--	Revised Plate 2

(Issued May 1976)

INVESTIGATION OF PERFORMANCE OF CONCRETE AND CONCRETING  
MATERIALS EXPOSED TO NATURAL WEATHERING

TECHNICAL REPORT NO. 6-553

June 1960

Supplements, Corrections, and Revisions  
Distribution No. 13\*

May 1976

VOLUME 1

ACTIVE INVESTIGATIONS

<u>Item</u>	<u>Part</u>	<u>Section</u>	<u>Supplement, Correction, or Revision</u>
✓1		Preface	Reprinted p iii; revised p iv
✓2		Contents	Revised p v and reprinted p vi
✓3	II		Revised Table 1 and reprinted Table 2
✓4	II	1	Revised sheet 3 of Table 1-TC-A
✓5	II	2	Revised sheets 8 and 9 of Table 1-TC-B
✓6	II	3	Revised sheet 2 of Table 1-SF
✓7	II	4	Revised Table 1-CRMI-PB (1 page)
✓8	II	5	A new item including Key (1 page), text (1 page), and Table 1-CERL-FC (1 page)
✓9	II	6	Revised sheets 2 and 3 of Table 2-PR; revised sheet 2 of Table 5-PR; revised sheet 3 of Table 6-PR
✓10	II	7	A new item including Key (1 page), text (1 page), and Table 1-WES-FC (1 page)
✓11	II	8	Revised sheet 5 of Table 1-CRMI-PD; revised sheet 3 of Table 2-CRMI-PD
✓12	II	9	Revised sheet 2 of Table 1-PQ

\* TR 6-553 was issued in June 1960. Distributions of Supplements, Corrections, and Revisions are issued each year. This distribution, No. 13, brings the report up to date as of June 1975.

(Issued May 1976)

<u>Item</u>	<u>Part</u>	<u>Section</u>	<u>Supplement, Correction, or Revision</u>
✓ 13	II	10	Revised sheet 1 and new sheet 2 of Table 1-SC; revised Table 2-SC (1 page)
✓ 14	II	11	Revised sheets 2, 3, and 4 of Table 1-BFS
✓ 15	II	12	Revised Table 1-SSFE (1 page)
✓ 16	II	13	Revised Table 1-TP (1 page)
✓ 17	II	14	Revised Table 1-4.5A (1 page)
✓ 18	II	17	Revised sheets 5, 6, 7, and 8 and new sheets 9, 10, 11, and 12 of Table 1-LTS
✓ 19	II	22	Revised Table 1-MM (1 page)
✓ 20	II	25	Revised sheet 6 of Table 1-CRA
✓ 21	II	26	Revised Table 1-OD (1 page)
✓ 22	II	27	Revised Key; reprinted sheet 3, revised sheet 4, new sheet 5; revised sheet 2 of Tables 1-KCD and 2-KCD; revised Tables 3-KCD, 4-KCD, and 5-KCD (1 page each); new Tables 6-KCD and 7-KCD (1 page each).
✓ 23	II	28	Revised Table 1-ED (1 page)
✓ 24	II	34	Revised Table 1-MCP (1 page)
✓ 25	II	35	Revised Tables 1-QA and 2-QA (1 page each)
✓ 26	II	37	Revised sheet 3 of Table 1-CAP
✓ 27	II	38	Revised sheet 2 of Table 1-MAWC
✓ 28	II	39	Revised sheet 2 of Table 1-CT
✓ 29	II	--	Revised Plate 2

(Issued Aug 1974)

INVESTIGATION OF PERFORMANCE OF CONCRETE AND CONCRETING  
MATERIALS EXPOSED TO NATURAL WEATHERING

TECHNICAL REPORT NO. 6-553

June 1960

Supplements, Corrections, and Revisions  
Distribution No. 12\*

August 1974

VOLUME 1

ACTIVE INVESTIGATIONS

<u>Item</u>	<u>Part</u>	<u>Section</u>	<u>Supplement, Correction, or Revision</u>
✓1		Preface	Reprinted p iii; revised p iv
✓2		Contents	Revised p v and reprinted p vi
✓3			Revised p vii
✓4	I		Revised pp 3 and 6; reprinted pp 4 and 5
✓5	II		Revised p 9 and Table 1, deleted Table 3
✓6	II	1	Revised sheet 3 of Table 1-TC-A
✓7	II	2	New sheets 8 and 9 of Table 1-TC-B
✓8	II	3	Revised sheet 1 of Table 1-SF; new sheet 2 of Table 1-SF
✓9	II	4	Revised Table 1-CRMI-PB (1 page)
✓10	II	6	Revised sheets 2 and 3 of Table 2-PR; sheet 2 of Table 5-PR; and sheet 3 of Table 6-PR
✓11	II	8	Revised sheet 4 of Table 1-CRMI-PD; new sheet 5 of Table 1-CRMI-PD; revised sheet 3 of Table 2-CRMI-PD
✓12	II	9	Revised sheet 2 of Table 1-PQ
✓13	II	10	Revised Tables 1-SC and 2-SC (1 page each)

\* TR 6-553 was issued in June 1960. Distributions 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11 were issued, respectively, in May 1962, August 1963, August 1964, August 1965, September 1966, September 1967, September 1968, September 1969, September 1970, January 1972, and January 1973. This distribution, No. 12, brings the report up to date as of August 1974.

(Issued Aug 1974)

<u>Item</u>	<u>Part</u>	<u>Section</u>	<u>Supplement, Correction, or Revision</u>
✓14	II	11	Revised sheets 2, 3, and 4 of Table 1-BFS
✓15	II	12	Revised Table 1-SSFE (1 page)
✓16	II	13	Revised Table 1-TP (1 page)
✓17	II	14	Revised Table 1-4.5A (1 page)
✓18	II	17	Revised sheets 5, 6, 7, and 8 of Table 1-LTS
✓19	II	22	Revised Table 1-MM (1 page)
✓20	II	25	Revised sheet 6 of Table 1-CRA
✓21	II	26	Revised Table 1-OD (1 page)
✓22	II	27	Revised sheet 2 of Tables 1-KCD and 2-KCD; revised Tables 3-KCD, 4-KCD, and 5-KCD (1 page each)
✓23	II	28	Revised Table 1-ED (1 page)
✓24	II	29	Reprinted p 1; revised p 2
✓25	II	30	Revised pp 1 and 2
✓26	II	34	Revised Table 1-MCP (1 page)
✓27	II	35	Revised Table 1-QA and 2-QA (1 page each)
✓28	II	37	Revised sheet 3 of Table 1-CAP
✓29	II	38	Revised sheet 2 of Table 1-MAWC
✓30	II	39	Revised sheet 2 of Table 1-CT
31	II	40	Revised Tables 1-MBC, 2-MBC, 3-MBC, and 4-MBC (1 page each)
32	II	--	Revised Plate 2

(Issued Jan 1973)

INVESTIGATION OF PERFORMANCE OF CONCRETE AND CONCRETING  
MATERIALS EXPOSED TO NATURAL WEATHERING

TECHNICAL REPORT NO. 6-553

June 1960

Supplements, Corrections, and Revisions  
Distribution No. 11\*

January 1973

VOLUME 1

ACTIVE INVESTIGATIONS

<u>Item</u>	<u>Part</u>	<u>Section</u>	<u>Supplement, Correction, or Revision</u>
✓1		Preface	Revised pp iii and iv
✓2		Contents	Revised p v; reprinted p vi
✓3	I	--	Reprinted pp 1 and 5 and Tables 2 and 3; revised pp 2 and 6 and Table 1 (1 page)
✓4	II	--	Revised p 10
✓5	II	1	Revised sheet 3 of Table 1-TC-A
✓6	II	2	Revised sheets 6 and 7 of Table 1-TC-B
✓7	II	3	Revised Table 1-SF (1 page)
✓8	II	4	Revised Table 1-CRMI-PB (1 page)
✓9	II	5	<u>Withdraw</u> Section 5 from this volume (see Vol 2, COMPLETED INVESTIGATIONS, Program 22)
✓10	II	6	Revised sheet 2 of Table 1-PR; sheets 2 and 3 of Table 2-PR; sheet 2 of Table 5-PR; and sheet 2 of Table 6-PR. New sheets 3 of Tables 1-PR and 6-PR
✓11	II	7	<u>Withdraw</u> Section 7 from this volume (see Vol 2, COMPLETED INVESTIGATIONS, Program 23)

\* TR 6-553 was issued in June 1960. Distributions 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 were issued, respectively, in May 1962, August 1963, August 1964, August 1965, September 1966, September 1967, September 1968, September 1969, September 1970, and January 1972. This distribution, No. 11, brings the report up to date as of January 1973.

(Issued Jan 1973)

Item	Part	Section	Supplement, Correction, or Revision
✓12	II	8	Revised sheet <u>4</u> of Table 1-CRMI-PD and sheet <u>3</u> of Table <u>2-CRMI-PD</u>
✓13	II	9	Revised sheet 2 of Table 1-PQ
✓14	II	10	Revised Tables 1-SC and 2-SC (1 page each)
✓15	II	11	Revised sheets 2, 3, and 4 of Table 1-BFS
✓16	II	12	Revised Table 1-SSFE (1 page)
✓17	II	13	A new item including Key (1 page), text (1 page), and Table 1-TP (1 page)
✓18	II	14	Revised Table 1-4.5A (1 page)
✓19	II	17	Revised sheets 5, 6, 7, and 8 of Table 1-LTS
✓20	II	22	Revised Table 1-MM (1 page)
✓21	II	25	Revised sheet 5 and new sheet 6 of Table 1-CRA
✓22	II	26	Revised Table 1-OD (1 page)
✓23	II	27	New sheets 2 of Tables 1- and 2-KCD; revised Tables 3-KCD, 4-KCD, and 5-KCD (1 page)
✓24	II	28	Revised Table 1-ED (1 page)
✓25	II	30	Reprinted p 1; revised p 2
✓26	II	34	Revised Table 1-MCP (1 page)
✓27	II	35	Revised Table 1-QA (1 page) and Table 2-QA (1 page)
✓28	II	37	Revised sheet 3 of Table 1-CAP
✓29	II	38	Revised sheet 2 of Table 1-MAWC
✓30	II	39	New sheet 2 of Table 1-CT (1 page)
✓31	II	40	Revised Tables 1-MBC, 2-MBC, 3-MBC, and 4-MBC
✓32	II	--	Revised Plates 1 and 2

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INVESTIGATION OF PERFORMANCE OF CONCRETE AND CONCRETING  
MATERIALS EXPOSED TO NATURAL WEATHERING

TECHNICAL REPORT NO. 6-553

June 1960

Supplements, Corrections, and Revisions  
Distribution No. 10\*

January 1972

VOLUME 1

ACTIVE INVESTIGATIONS

<u>Item</u>	<u>Part</u>	<u>Section</u>	<u>Supplement, Correction, or Revision</u>
1		Preface	Revised pp iii and iv
2	I	--	Reprinted p 1; revised pp 2, 3, 4, 5, 6, Tables 1, 2, and 3
3	II	--	Revised p 11
4	II	1	Revised sheet 3 of Table 1-TC-A
5	II	2	Revised sheets 6 and 7 of Table 1-TC-B
6	II	3	Revised Table 1-SF (1 p)
7	II	4	Revised Table 1-CRMI-PB (1 p)
8	II	5	Revised Tables 1-PF and 2-PF (1 p ea)
9	II	6	Revised sheet 2 of Table 1-PR; revised sheets 2 and 3 of Table 2-PR; revised Table 3-PR (1 p); revised sheet 2 of Table 5-PR; revised sheet 2 of Table 6-PR
10	II	7	Revised Table 1-GLD (1 p)
11	II	8	Revised sheet 4 of Table 1-CRMI-PD; revised sheet 3 of Table 2-CRMI-PD
12	II	9	Revised sheet 2 of Table 1-PQ
13	II	10	Revised Tables 1-SC (1 p) and 2-SC (1 p)

\* TR 6-553 was issued in June 1960. Distributions 1, 2, 3, 4, 5, 6, 7, 8, and 9 were issued, respectively, in May 1962, August 1963, August 1964, August 1965, September 1966, September 1967, September 1968, September 1969, and September 1970. This distribution, No. 10, brings the report up to date as of January 1972.

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<u>Item</u>	<u>Part</u>	<u>Section</u>	<u>Supplement, Correction, or Revision</u>
14	II	11	Reprinted p 1; revised p 2; revised sheets 2, 3, and 4 of Table 1-BFS
15	II	12	Revised Table 1-SSFE (1 p)
16	II	14	Revised Table 1-4.5A (1 p)
17	II	17	Revised p 1; revised sheets 5, 6, 7, and 8 of Table 1-LTS
18	II	22	Revised Table 1-MM (1 p)
19	II	25	Revised sheets 4 and 5 of Table 1-CRA
20	II	26	Revised Tables 1-OD (1 p) and 2-OD (1 p)
21	II	27	Revised Tables 1-KCD (1 p), 2-KCD (1 p), 3-KCD (1 p), 4-KCD (1 p), and 5-KCD (1 p)
22	II	28	Revised Table 1-ED (1 p)
23	II	29	Reprinted p 1; revised p 2
24	II	30	Reprinted p 1; revised p 2; revised sheets 2 and 5 of Table 1-WS; revised sheets 1 and 2 of Table 3-WS; revised sheets 1, 2, 3, and 4 of Table 4-WS
25	II	32	Revised p 1
26	II	34	Revised Table 1-MCP (1 p)
27	II	35	Revised Tables 1-QA (1 p) and 2-QA (1 p)
28	II	36	Revised Table 1-CRMI-PG (1 p)
29	II	37	Revised sheet 3 of Table 1-CAP
30	II	38	Revised sheet 2 of Table 1-MAWC
31	II	39	Revised sheets 1 and 2 of Table 1-CT
32	II	40	Revised key; revised p 1; revised Tables 1-MBC (1 p) and 2-MBC (1 p); new tables 3-MBC (1 p) and 4-MBC (1 p)
33	II		Revised Plate 1
34	II		Revised Plate 2
35	II		Revised Plate 3

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INVESTIGATION OF PERFORMANCE OF CONCRETE AND CONCRETING

MATERIALS EXPOSED TO NATURAL WEATHERING

TECHNICAL REPORT NO. 6-553

June 1960

Supplements, Corrections, and Revisions  
Distribution No. 9\*

September 1970

VOLUME I

ACTIVE INVESTIGATIONS

Item	Part	Section	Supplement, Correction, or Revision
1		Preface	Reprinted p iii; revised p iv
2		Contents	Revised p v; reprinted p vi
3	I	--	Revised Tables 1, 2, and 3 (1 p ea)
4	II	--	Revised p 11
5	II	1	Revised sheet 3 of Table 1-TC-A
6	II	2	Revised sheets 6 and 7 of Table 1-TC-B
7	II	3	Revised Table 1-SF (1 p)
8	II	4	Revised Table 1-CRMI-PB (1 p)
9	II	5	Revised Table 1-PF (1 p); new Table 2-PF (1 p)
10	II	6	Revised sheet 2 of Table 1-PR; revised sheets 2 and 3 of Table 2-PR; revised Table 3-PR (1 p); revised Table 4-PR (1 p); revised sheet 2 of Table 5-PR; revised sheet 2 of Table 6-PR
11	II	7	Revised Table 1-GLD (1 p)
12	II	8	Revised sheet 4 of Table 1-CRMI-PD; revised sheet 2 and new sheet 3 of Table 2-CRMI-PD
13	II	9	Revised sheet 2 of Table 1-PQ
14	II	10	Revised Tables 1-SC (1 p) and 2-SC (1 p)

\* TR 6-553 was issued in June 1960. Distributions 1, 2, 3, 4, 5, 6, 7, and 8 were issued, respectively, in May 1962, August 1963, August 1964, August 1965, September 1966, September 1967, September 1968, and September 1969. This distribution, No. 9, brings the report up to date as of September 1970.

(Issued Sept 1970)

<u>Item</u>	<u>Part</u>	<u>Section</u>	<u>Supplement, Correction, or Revision</u>
15	II	11	Revised sheets 2, 3, and 4 of Table 1-BFS; revised sheets 2, 3, and 4 of Table 2-BFS
16	II	12	Revised Table 1-SSFE (1 p)
17	II	13	<u>Withdraw</u> Section 13 from this volume (see Vol 2, COMPLETED INVESTIGATIONS, Program 21)
18	II	14	Revised Table 1-4.5A (1 p)
19	II	17	Revised sheets 5, 6, 7, and 8 of Table 1-LTS; revised sheets 1, 2, 3, and 4 of Table 2-LTS
20	II	22	Revised Table 1-MM (1 p)
21	II	25	Revised sheets 4 and 5 of Table 1-CRA
22	II	26	Revised Table 1-OD (1 p); revised Table 2-OD (1 p)
23	II	27	Revised Table 1-KCD (1 p); revised Table 2-KCD (1 p); revised Table 3-KCD (1 p); revised Table 4-KCD (1 p); revised Table 5-KCD (1 p)
24	II	28	Revised Table 1-ED (1 p)
25	II	29	Revised sheets 3 and 4 of Table 1-AA; revised Table 2-AA (1 p)
26	II	30	Revised sheets 2 and 5 of Table 1-WS; revised sheets 2 and 3 of Table 2-WS; revised sheets 1 and 2 of Table 3-WS; revised sheets 2, 3, and 4 of Table 4-WS
27	II	31	Revised key, revised pp 1 and 2; revised Table 1-WPF (1 p)
28	II	32	Revised sheet 2 of Table 1-SS
29	II	34	Revised Table 1-MCP (1 p)
30	II	35	Revised Table 1-QA (1 p); revised Table 2-QA (1 p)
31	II	36	Revised p 1; revised Table 1-CRMI-PG (1 p)
32	II	37	Revised sheet 2 of Table 1-CAP; new sheet 3 of Table 1-CAP
33	II	38	Revised sheet 2 of Table 1-MAWC
34	II	39	Revised sheets 1 and 2 of Table 1-CT
35	II	40	Revised key; revised p 1; revised Table 1-MBC; new Table 2-MBC (1 p)
36	II	--	Revised Plates 1, 2, and 3 (1 p ea)

(Issued Sept 1970)

VOLUME 2

COMPLETED INVESTIGATIONS

<u>Item</u>	<u>Part</u>	<u>Program</u>	<u>Supplement, Correction, or Revision</u>
37			Revised Contents (1 p)
38	III	--	New p 3
39	III	21	A new item (including key (2 pp); 7 pp of text; and Tables 1-CRE, 2-CRE, and 3-CRE)

(Issued Sept 1969)

INVESTIGATION OF PERFORMANCE OF CONCRETE AND CONCRETING

MATERIALS EXPOSED TO NATURAL WEATHERING

TECHNICAL REPORT NO. 6-553

June 1960

Supplements, Corrections, and Revisions  
Distribution No. 8\*

September 1969

VOLUME I

ACTIVE INVESTIGATIONS

<u>Item</u>	<u>Part</u>	<u>Section</u>	<u>Supplement, Correction, or Revision</u>
1		Preface	Reprinted p iii; revised p iv
2		Contents	Revised p v; reprinted p vi
3	I	--	Reprinted p 5; revised p 6; revised Tables 1, 2, and 3 (1 p ea)
4	II	--	Revised p 11
5	II	1	Revised sheet 3 of Table 1-TC-A
6	II	2	Revised sheets 6 and 7 of Table 1-TC-B
7	II	3	Revised Table 1-SF (1 p)
8	II	4	Revised Table 1-CRMI-PB (1 p)
9	II	5	Revised Tables 1-PF and 2-PF (same page)
10	II	6	Revised sheet 2 of Table 1-PR; revised sheets 2 and 3 of Table 2-PR; revised Table 3-PR (1 p); revised sheet 1 and new sheet 2 of Table 5-PR; revised sheet 2 of Table 6-PR
11	II	7	Revised Table 1-GLD (1 p)
12	II	8	Revised sheet 3 and new sheet 4 of Table 1-CRMI-PD; revised sheet 2 of Table 2-CRMI-PD
13	II	9	Revised sheet 1 and new sheet 2 of Table 1-PQ
14	II	10	Revised Tables 1-SC (1 p) and 2-SC (1 p)

\* TR 6-553 was issued in June 1960. Distributions 1, 2, 3, 4, 5, 6, and 7 were issued, respectively, in May 1962, August 1963, August 1964, August 1965, September 1966, September 1967, and September 1968. This distribution, No. 8, brings the report up to date as of September 1969.

(Issued Sept 1969)

<u>Item</u>	<u>Part</u>	<u>Section</u>	<u>Supplement, Correction, or Revision</u>
15	II	11	Revised sheets 2, 3, and 4 of Table 1-BFS
16	II	12	A new item (including key; 1 p of text; and Table 1-SSFE (1 p))
17	II	13	Revised sheet 5, reprinted sheet 6, and revised sheet 7 of Table 1-CRE; revised sheet 2 of Table 2-CRE
18	II	14	A new item (including key; 1 p of text; and Table 1-4.5A (1 p))
19	II	17	Revised sheets 5, 6, 7, and 8 of Table 1-LTS
20	II	22	Revised Table 1-MM (1 p)
21	II	25	Revised sheets 4 and 5 of Table 1-CRA
22	II	26	Revised Table 1-OD (1 p); revised Table 2-OD (1 p)
23	II	27	Additional key (1 p); revised p 3 and new p 4; revised Table 1-KCD (1 p); revised Table 2-KCD (1 p); revised Table 3-KCD (1 p); revised Table 4-KCD (1 p); new Table 5-KCD (1 p)
24	II	28	Revised Table 1-ED (1 p)
25	II	30	Revised sheets 1, 2, 3, and 4, new sheet 5, and revised sheets 6 and 7 of Table 1-WS; revised sheets 1, 2, and 3 of Table 2-WS; revised sheets 1 and 2 of Table 3-WS; revised sheets 2, 3, and 4 of Table 4-WS
26	II	34	Revised Table 1-MCP (1 p)
27	II	35	Revised Table 1-QA (1 p); revised Table 2-QA (1 p)
28	II	36	Revised p 1; revised Table 1-CRMI-PG (1 p)
29	II	37	Revised sheet 2 of Table 1-CAP
30	II	38	Revised sheet 2 of Table 1-MAWC
31	II	39	Revised sheets 1 and 2 of Table 1-CT
32	II	40	A new item (including key; 1 p of text; and Table 1-MBC (1 p))
33	II	--	Revised Plates 1 and 2 (1 p ea)

(Issued Sept 1968)

INVESTIGATION OF PERFORMANCE OF CONCRETE AND CONCRETING

MATERIALS EXPOSED TO NATURAL WEATHERING

TECHNICAL REPORT NO. 6-553

June 1960

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Distribution No. 7\*

September 1968

VOLUME 1

ACTIVE INVESTIGATIONS

<u>Item</u>	<u>Part</u>	<u>Section</u>	<u>Supplement, Correction, or Revision</u>
1	Preface		Reprinted p iii; revised p iv
2	Contents		Revised pp v and vi
3	Conversion factors		Revised p vii
4	I	--	Revised pp 1, 2, 3, 4, 5, and 6; revised Tables 1, 2, and 3
5	II	1	Revised sheets 1, 2, and 3 of Table 1-TC-A
6	II	2	Revised sheets 5 and 6 of Table 1-TC-B; new sheet 7 of Table 1-TC-B
7	II	3	Revised Table 1-SF (1 p)
8	II	4	Revised p 1; revised Table 1-CRMI-PB (1 p)
9	II	5	Revised Tables 1-PF and 2-PF (same page)
10	II	6	Revised sheets 1 and 2 of Table 1-PR; revised sheet 2 and new sheet 3 of Table 2-PR; revised Table 3-PR (1 p); revised Table 4-PR (1 p); revised Table 5-PR (1 p); revised sheets 1 and 2 of Table 6-PR
11	II	7	Revised Table 1-GID (1 p)
12	II	8	Revised p 1; revised sheets 2 and 3 of Table 1-CRMI-PD; revised sheets 1 and 2 of Table 2-CRMI-PD
13	II	9	Revised Table 1-PQ (1 p)
14	II	10	Revised Table 1-SC (1 p); revised Table 2-SC (1 p)

\* TR 6-553 was issued in June 1960. Distributions 1, 2, 3, 4, 5, and 6 were issued, respectively, in May 1962, August 1963, August 1964, August 1965, September 1966, and September 1967. This distribution, No. 7, brings the report up to date as of September 1968.

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<u>Item</u>	<u>Part</u>	<u>Section</u>	<u>Supplement, Correction, or Revision</u>
15	II	11	Revised pp 1 and 2; revised sheet 2 and new sheets 3 and 4 of Table 1-BFS; revised sheet 2 and new sheets 3 and 4 of Table 2-BFS
16	II	13	Revised sheet 3, reprinted sheet 4, revised sheets 5, 6, and 7 of Table 1-CRE; revised sheet 2 of Table 2-CRE; revised sheets 3, 4, 5, and 6 of Table 3-CRE
17	II	17	Revised p 1; revised sheets 5, 6, 7, and 8 of Table 1-LTS; revised sheets 1, 2, 3, and 4 of Table 2-LTS
18	II	22	Revised Table 1-MM (1 p)
19	II	25	Revised sheets 3, 4, and 5 of Table 1-CRA
20	II	26	Revised Table 1-OD (1 p); revised Table 2-OD (1 p)
21	II	27	Revised Table 1-KCD (1 p); revised Table 2-KCD (1 p); revised Table 3-KCD (1 p); revised Table 4-KCD (1 p)
22	II	28	Revised Table 1-ED (1 p)
23	II	29	Revised sheets 3 and 4 of Table 1-AA; revised Table 2-AA (1 p)
24	II	30	Revised sheets 2 and 4 of Table 1-WS; revised sheets 2 and 3 of Table 2-WS; revised sheets 1 and 2 of Table 3-WS; revised sheets 2, 3, and 4 of Table 4-WS
25	II	32	Revised sheet 2 of Table 1-SS
26	II	34	Revised Table 1-MCP (1 p)
27	II	35	Revised Tables 1-QA and 2-QA (same page)
28	II	36	Revised Table 1-CRMI-PG (1 p)
29	II	37	Revised sheet 2 of Table 1-CAP
30	II	38	Revised sheet 1 and new sheet 2 of Table 1-MAWC
31	II	39	A new item (including key; 1 p of text; and Table 1-CT (2 pp))
32	II	--	Revised Plates 1, 2, and 3

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VOLUME 1

ACTIVE INVESTIGATIONS

<u>Item</u>	<u>Part</u>	<u>Section</u>	<u>Supplement, Correction, or Revision</u>
1		Preface	Reprinted p iii; revised p iv
2		Contents	Revised pp v and vi
3	I	--	Revised Table 1; reprinted Table 2; revised Table 3
4	II	--	Revised p 11
5	II	1	Revised sheet 3 of Table 1-TC-A
6	II	2	Revised sheets 5 and 6 of Table 1-TC-B
7	II	3	Revised Table 1-SF
8	II	4	Revised Table 1-CRMI-PB
9	II	5	Revised Tables 1-PF and 2-PF (same page)
10	II	6	Reprinted p 5; new p 6; revised sheet 2 of Table 1-PR; revised sheets 1 and 2 of Table 2-PR; revised Table 4-PR; revised Table 5-PR; revised sheet 2 of Table 6-PR
11	II	7	Revised Table 1-GLD
12	II	8	Revised sheets 2 and 3 of Table 1-CRMI-PD; revised sheet 2 of Table 2-CRMI-PD
13	II	9	Revised Table 1-PQ
14	II	10	Revised Tables 1-SC and 2-SC
15	II	11	Revised sheets 1 and 2 of Table 1-BFS

\* TR 6-553 was issued in June 1960. Distributions 1, 2, 3, 4, and 5 were issued, respectively, in May 1962, August 1963, August 1964, August 1965, and September 1966. This distribution, No. 6, brings the report up to date as of September 1967.

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<u>Item</u>	<u>Part</u>	<u>Section</u>	<u>Supplement, Correction, or Revision</u>
16	II	12	<u>Withdraw</u> Section 12 from this volume (see Vol 2, COMPLETED INVESTIGATIONS, Program 10)
17	II	13	Revised sheets 5 and 7 of Table 1-CRE; revised sheet 2 of Table 2-CRE
18	II	14	<u>Withdraw</u> Section 14 from this volume (see Vol 2, COMPLETED INVESTIGATIONS, Program 11)
19	II	15	<u>Withdraw</u> Section 15 from this volume (see Vol 2, COMPLETED INVESTIGATIONS, Program 13)
20	II	16	<u>Withdraw</u> Section 16 from this volume (see Vol 2, COMPLETED INVESTIGATIONS, Program 14)
21	II	17	Revised sheets 5, 6, 7, and 8 of Table 1-LTS
22	II	18	<u>Withdraw</u> Section 18 from this volume. The results of this study will be issued in Distribution No. 7 (1968) as Program 17 of Vol 2, COMPLETED INVESTIGATIONS
23	II	19	<u>Withdraw</u> Section 19 from this volume (see Vol 2, COMPLETED INVESTIGATIONS, Program 12)
24	II	20	<u>Withdraw</u> Section 20 from this volume (see Vol 2, COMPLETED INVESTIGATIONS, Program 15)
25	II	21	<u>Withdraw</u> Section 21 from this volume (see Vol 2, COMPLETED INVESTIGATIONS, Program 16)
26	II	22	Revised Table 1-MM
27	II	23	<u>Withdraw</u> Section 23 from this volume. The results of this study will be issued in Distribution No. 7 (1968) as Program 18 of Vol 2, COMPLETED INVESTIGATIONS
28	II	24	<u>Withdraw</u> Section 24 from this volume. The results of this study will be issued in Distribution No. 7 (1968) as Program 19 of Vol 2, COMPLETED INVESTIGATIONS
29	II	25	Revised sheets 4 and 5 of Table 1-CRA
30	II	26	Revised Tables 1-OD and 2-OD
31	II	27	Revised Table 1-KCD; revised Table 2-KCD; revised Table 3-KCD; revised Table 4-KCD
32	II	28	Revised Table 1-ED
33	II	30	Revised sheets 2 and 4 of Table 1-WS; revised sheets 1 and 2 of Table 3-WS; revised sheets 2, 3, and 4 of Table 4-WS
34	II	31	Revised p 1; new p 2; revised Table 1-WPF

(Issued Sept 1967)

<u>Item</u>	<u>Part</u>	<u>Section</u>	<u>Supplement, Correction, or Revision</u>
35	II	33	<u>Withdraw</u> Section 33 from this volume. The results of this study will be issued in Distribution No. 7 (1968) as Program 20 of Vol 2, COMPLETED INVESTIGATIONS
36	II	34	Revised Table 1-MCP
37	II	35	Revised Table 1-QA; revised Table 2-QA (same page)
38	II	36	Revised Table 1-CRMI-PG
39	II	37	Revised sheet 2 of Table 1-CAP
40	II	38	Revised Table 1-MAWC
41	II	--	Revised Plates 1 and 2

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VOLUME 1

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<u>Item</u>	<u>Part</u>	<u>Section</u>	<u>Supplement, Correction, or Revision</u>
✓1		Preface	Reprinted p iii; revised p iv
✓2		Contents	Revised p v; reprinted p vi
✓3		Conversion Factors	(New section.) p vii
✓4		Summary	Revised p ix
✓5	I	--	Revised pp 1, 2, 3, and 4; new sheet 5; revised Tables 1, 2, and 3
✓6	II	--	Revised p 11
✓7	II	1	Revised sheet 3 of Table 1-TC-A**
✓8	II	2	Revised sheets 5 and 6 of Table 1-TC-B**
✓9	II	3	Revised Table 1-SF**
✓10	II	4	Revised Table 1-CRMI-PB**
✓11	II	5	Revised Tables 1-PF and 2-PF (same page)**

\* TR 6-553 was issued in June 1960. Distributions 1, 2, 3, and 4 were issued respectively in May 1962, August 1963, August 1964, and August 1965. This distribution, No. 5, brings the report up to date as of September 1966.

\*\* Pulse velocities are not given for all specimens in these Treat Island programs for 1966. Values were obtained but they were determined with the James Soniscope ("V-scope") and appear to be too low when compared with previous readings taken with the McPhar Soniscope. An effort has been made to establish a factor for use in adjusting these readings, but has not yet been successful.

(Issued Sept 1966)

<u>Item</u>	<u>Part</u>	<u>Section</u>	<u>Supplement, Correction, or Revision</u>
✓12	II	6	Revised sheet 1 and new sheet 2 of Table 1-PR; revised sheets 1 and 2 of Table 2-PR; revised Table 3-PR; revised Table 5-PR; revised sheet 1 and new sheet 2 of Table 6-PR**
✓13	II	7	Revised Table 1-GLD
✓14	II	8	Revised sheets 2 and 3 of Table 1-CRMI-PD; revised sheet 2 of Table 2-CRMI-PD**
✓15	II	9	Revised Table 1-PQ
✓16	II	10	Revised Key; revised sheet 1; new sheet 2; revised Table 1-SC; new Table 2-SC
✓17	II	11	Revised sheets 1 and 2 of Table 1-BFS; revised sheets 1 and 2 of Table 2-BFS
✓18	II	12	Revised sheet 3 of Table 1-NBS
✓19	II	13	Revised sheets 5 and 7 of Table 1-CRE; revised sheet 2 of Table 2-CRE; revised sheets 3, 4, 5, and 6 of Table 3-CRE
✓20	II	14	Revised Table 1-ADB
✓21	II	15	Revised sheet 4 of Table 1-CRN
✓22	II	16	Revised sheet 6 of Table 1-VR; new sheets 7 and 8 of Table 1-VR
✓23	II	17	Revised sheet 1; revised sheets 5, 6, 7, and 8 of Table 1-LTS
✓24	II	18	Revised sheet 2 of Table 2-PCA
✓25	II	19	Revised Table 1-SY
✓26	II	20	Revised sheet 4 of Table 2-FLC
✓27	II	21	Revised sheet 2 of Table 1-FL
✓28	II	22	Revised Table 1-MM
✓29	II	23	Revised sheet 2 of Table 1-VP; revised Table 2-VP
✓30	II	24	Revised Table 1-PK
✓31	II	25	Revised sheets 4 and 5 of Table 1-CRA
✓32	II	26	Revised Table 1-OD; revised Table 2-OD
✓33	II	27	Revised Table 1-KCD; revised Table 2-KCD; revised Table 3-KCD; revised Table 4-KCD
✓34	II	28	Revised Table 1-ED
✓35	II	29	Revised sheet 2 of Table 1-AA; new sheets 3 and 4 of Table 1-AA; revised Table 2-AA

(Issued Sept 1966)

<u>Item</u>	<u>Part</u>	<u>Section</u>	<u>Supplement, Correction, or Revision</u>
36	II	30	New sheet 2 of Table 1-WS; revised sheets 3, 4, 5, and 6 of Table 1-WS; revised sheet 2 and new sheet 3 of Table 2-WS; revised sheets 1 and 2 of Table 3-WS; revised sheets 1, 2, and 4 of Table 4-WS
✓ 37	II	31	Revised Table 1-WPF
✓ 38	II	32	Revised Table 1-SS
✓ 39	II	33	Revised sheet 2 of Table 1-Z
✓ 40	II	34	Revised Table 1-MCP
✓ 41	II	35	Revised Table 1-QA
✓ 42	II	36	Revised Table 1-CRMI-PG
✓ 43	II	37	Revised sheet 1 and new sheet 2 of Table 1-CAP
✓ 44	II	38	Revised Table 1-MAWC
✓ 45	II	--	Revised Plates 1, 2, and 3

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MATERIALS EXPOSED TO NATURAL WEATHERING

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VOLUME 1

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<u>Item</u>	<u>Part</u>	<u>Section</u>	<u>Supplement, Correction, or Revision</u>
1	Preface and Contents		Reprinted p iii; revised p iv; reprinted p v; revised p vi
2	I	--	Revised sheets 1 and 2 of Table 1; reprinted Table 2; revised Table 3
3	II	1	Revised Key; revised sheet 1; revised sheets 1-3 of Table 1-TC-A
4	II	2	Revised sheet 1; revised sheets 1-5 and new sheet 6 of Table 1-TC-B
5	II	3	Corrected sheet 1; revised Table 1-SF
6	II	4	Corrected sheet 1; revised Table 1-CRMI-PB
7	II	5	Revised Tables 1-PF and 2-PF (same page)
8	II	6	Revised sheet 5; revised Table 1-PR; revised sheets 1 and 2 of Table 2-PR; revised Table 5-PR; new Table 6-PR

\* TR 6-553 was issued in June 1960. It was intended that there be issued annually thereafter a distribution of replacement and supplementary sheets by means of which the report would be kept up to date. Distributions 1, 2, and 3 were issued respectively in May 1962, August 1963, and August 1964. This distribution, No. 4, brings the report up to date as of August 1965. It is planned to issue future distributions annually as of August of each year. It is further planned that specimen testing at the various installations be accomplished in May in those years when such testing is to be done, and to schedule formal inspections of the specimens after the distribution of data including the results of such May inspections; thus formal inspections would probably be scheduled during September of any year in which it might be determined that a formal inspection should be made.

(Issued Aug 1965)

<u>Item</u>	<u>Part</u>	<u>Section</u>	<u>Supplement, Correction, or Revision</u>
9	II	7	Revised Table 1-GLD
10	II	8	Corrected sheet 1; revised sheets 2 and 3 of Table 1-CRMI-PD; revised sheet 2 of Table 2-CRMI-PD
11	II	9	Corrected sheet 1, reprinted sheet 2, revised Table 1-PQ
12	II	10	Revised Table 1-SC
13	II	11	Revised sheets 1 and 2 of Table 1-BFS
14	II	12	Revised sheet 1; revised sheet 3 of Table 1-NBS
15	II	13	Corrected sheet 1, reprinted sheet 2, corrected sheet 3, reprinted sheet 4; revised sheets 5 and 7 of Table 1-CRE; revised sheet 2 of Table 2-CRE
16	II	14	Revised Table 1-ADB
17	II	15	Revised sheet 4 of Table 1-CRN
18	II	16	Revised sheets 4, 5, and 6 of Table 1-VR
19	II	17	Revised sheet 4 of Table 1-LTS; new sheets 5, 6, 7, and 8 of Table 1-LTS
20	II	18	Corrected sheet 1; revised sheet 2 of Table 2-PCA
21	II	19	Corrected sheet 1; revised Table 1-SY
22	II	20	Revised sheet 4 of Table 2-FLC
23	II	21	Revised sheet 2 of Table 1-FL
24	II	22	Revised Key; revised Table 1-MM
25	II	23	Revised sheet 2 of Table 1-VP; revised Table 2-VP
26	II	24	Revised Table 1-PK
27	II	25	Revised sheets 4 and 5 of Table 1-CRA
28	II	26	Revised Key; revised sheet 1; revised Table 1-OD; new Table 2-OD
29	II	27	Revised Table 1-KCD; revised Table 2-KCD; revised Table 3-KCD; revised Table 4-KCD
30	II	28	Corrected sheet 1; revised Table 1-ED
31	II	30	Revised sheets 1 and 3 of Table 1-WS; revised sheets 1 and 2 of Table 3-WS; revised sheets 1, 2, and 3 and new sheet of Table 4-WS
32	II	33	Corrected sheet 1; corrected sheet 1 and revised sheet 2 of Table 1-Z
33	II	34	Revised Table 1-MCP
34	II	35	Corrected sheet 1; revised Table 1-QA

(Issued Aug 1965)

<u>Item</u>	<u>Part</u>	<u>Section</u>	<u>Supplement, Correction, or Revision</u>
35	II	36	Corrected Key and sheet 1; revised Table 1-CRMI-PG
36	II	37	Corrected Key; revised Table 1-CAP
37	II	38	(New section). Key, sheet 1, and Table 1-MAWC
38			Revised Plates 1 and 2

(Revised August 1977)

#### PREFACE

The establishment of exposure stations, and the conduct of programs of investigation relative to the durability of concrete exposed to natural weathering have been authorized from time to time by the Office, Chief of Engineers. The initial installation of concrete specimens at an exposure station was made at Treat Island, Maine, in 1936 by the Concrete Laboratory of the Passamaquoddy Tidal Power Project. In 1939 the Office, Chief of Engineers, authorized the Central Concrete Laboratory, North Atlantic Division, to develop data relative to the durability of concrete exposed to severe weathering. Under this authorization specimens were prepared and installed at exposure stations in Maine, Florida, and New York. In 1946, the Office, Chief of Engineers, directed the Concrete Research Division (now Concrete Laboratory) of the U. S. Army Engineer Waterways Experiment Station (WES) (successor to the Central Concrete Laboratory) to continue the work in connection with these exposure stations. Further authority is contained in multiple letter of the Office, Chief of Engineers, dated 14 September 1948, subject, "Civil Works Investigations of Office, Chief of Engineers," Item CW-604-Concrete "Continuation of Permanent Exposure Stations." Additional authorizations have been provided since that time for the making and installing of specific specimens at these exposure stations. Installation and testing of specimens at the Florida station was discontinued in November 1971.

Results of these various investigations have been reported from time to time in the reports listed below.

1. Corps of Engineers, Central Concrete Laboratory, Cement Durability Program, First Interim Report, June 1942.
2. \_\_\_\_\_, Concrete Research, Laboratory Studies of Concrete Containing Air-Entraining Admixtures, Second Interim Report, Part I, July 1945.

(Revised August 1977)

3. Waterways Experiment Station, Concrete Research, Third Interim Report, Durability of Concrete Exposed to Natural Weathering, Technical Memorandum No. 6-226, August 1947.
4. \_\_\_\_\_, Concrete Research, Third Interim Report, Supplement No. 1, Durability of Concrete Exposed to Natural Weathering, Technical Memorandum No. 6-226, June 1950.
5. \_\_\_\_\_, Investigation of Durability of Concrete Exposed to Natural Weathering, Report No. 5, Summary of Results 1936-1953, Technical Memorandum No. 6-226, May 1954.
6. \_\_\_\_\_, Cement Durability Program, Long-Term Field Exposure of Concrete Columns, Technical Report C-72-2, August 1972.
7. Roshore, E. C. and Houston, B. J., Investigation of Plastic and Rubber-Based Coatings Used in Lieu of Rubbed Finishes on Formed Concrete Surfaces, sponsored by the Assistant Secretary of the Army (R&D), Department of the Army; Miscellaneous Paper No. 6-864, November 1966.
8. Houston, B. J., Investigation of Nonmetallic Waterstops; Preliminary Laboratory and Field Exposure Tests, sponsored by Office, Chief of Engineers, U. S. Army; Technical Report No. 6-546, Report No. 1, May 1960.
9. \_\_\_\_\_, Investigation of Nonmetallic Waterstops; Progress Report of Laboratory and Field Exposure Tests, sponsored by Office, Chief of Engineers, U. S. Army; Technical Report No. 6-546, Report No. 3, June 1963.
10. \_\_\_\_\_, Investigation of Nonmetallic Waterstops Effect of Exposure, sponsored by Office, Chief of Engineers, U. S. Army; Technical Report No. 6-546, Report No. 6, January 1968.
11. Kennedy, T. B., Tensile Crack Exposure Tests, CWI Item No. 026, Tensile Crack Exposure Test for Reinforced Concrete Beams, Technical Memorandum No. 6-412, U. S. Army Engineer Waterways Experiment Station, CE, July 1955.
12. Roshore, E. C., Durability and Behavior of Prestressed Concrete Beams, Pretensioned Concrete Investigation; Progress to July 1960, Technical Report No. 6-570, Report 1, June 1961.
13. \_\_\_\_\_, Tensile Crack Exposure Tests; Results of Tests of Reinforced Concrete Beams, Technical Memorandum No. 6-412, Report 2, November 1964.

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14. Roshore, E. C., Durability and Behavior of Prestressed Concrete Beams; Posttensioned Concrete Investigation, Progress to July 1966, Technical Report No. 6-570, Report No. 6-570, Report 2, March 1967.
15. \_\_\_\_\_, Field Exposure Tests of Reinforced Concrete Beams, Miscellaneous Paper No. 6-868, January 1967.
16. \_\_\_\_\_, Durability and Behavior of Prestressed Concrete Beams; Laboratory Tests of Weathered Pretensioned Beams, Technical Report No. 6-570, Report 3, October 1971.
17. O'Neil, E. F., Durability and Behavior of Prestressed Concrete Beams; Posttensioned Concrete Beam Investigation with Laboratory Tests from June 1961 to September 1975, Technical Report No. 6-570, Report 4, February 1977.
18. \_\_\_\_\_, Durability and Behavior of Prestressed Concrete Beams; Laboratory Tests of Weathered Pretensioned Beams, Technical Report No. 6-570, Report 5, June 1976.

This report summarizes all investigations made to date, and is issued in loose-leaf form in order that it may be kept up to date by the addition of new material or revision of old material, as appropriate. The report is made up of two volumes: Volume 1 (this volume) summarizes the test results of investigations which are still active, and Volume 2 summarizes the findings of completed investigations.

The major part of the work reported herein and the preparation of this report constitute part of Civil Works Investigation Item ES-630, "Field Exposure Durability Studies of Concrete." The studies were made by the Concrete Laboratory, Waterways Experiment Station. Personnel actively engaged in the direction and conduct of the work include Ms. K. Mather, Messrs. B. Mather, John Scanlon, B. R. Sullivan, R. V. Tye, Jr., E. E. McCoy, E. C. Roshore, H. T. Thornton, R. E. Black, Dale Glass, and G. S. Harris. Mr. Thornton prepared this distribution.

During the preparation of this report COL Edmund H. Lang, CE, was Director of the Waterways Experiment Station, and Mr. J. B. Tiffany was Technical Director. During the preparation of this distribution of the Supplements, Corrections, and Revisions, COL John L. Cannon, CE, was Commander and Director and Mr. F. R. Brown was Technical Director.

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- Section 26: Omaha District Aggregate Program
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- Section 28: Eufaula Dam Aggregates Study (Tulsa)
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- Section 30: Nonmetallic Waterstop Investigation (CW, LMVD)
- Section 31: Woven Plastic Test Program (CW R&D)
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- Section 34: Membrane Curing Program (CW R&D)
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- Section 36: Cement-Replacement Materials Investigation, Phase G (CW R&D)
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- Section 39: Curing Investigation (CW R&D)
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PLATES 1-3

(Issued August 1977)

CONVERSION FACTORS, U. S. CUSTOMARY TO  
METRIC (SI) UNITS OF MEASUREMENT

1 inch = 25.4 millimetres  
1 inch = 2.54 centimetres  
1 foot = 30.48 centimetres  
1 foot = 0.3048 metre  
37°F = 2.8°C  
-10°F = -23.4°C  
28°F = -2.2°C  
70°F = 21.1°C  
1 lb = 0.453592 kilogram  
1 bag of cement = 94 lb of cement = 42.637648 kilograms of cement  
1 cu yd = 0.764555 cubic metre  
1 gal (U. S.) = 3785.412 cubic centimetres  
1 gal (U. S.) = 3.785412 cubic decimetres  
1 cu ft = 0.028317 cubic metre  
1 ton = 2000 lb = 907.184 kilograms  
1 psi = 0.006894757 megapascals  
1 fps = 0.3048 metre/second  
1 lb/cu ft = 16.018477 kilograms/cubic metre  
1 bag/cu yd = 55.767928 kilograms/cubic metre  
1 gal/bag = 88.781398 cubic centimetres/kilogram  
3-1/2 by 4-1/2 by 16 in. = approximately 9 by 11-1/2 by 41 centimetres  
6 by 6 by 30 in. = approximately 15 by 15 by 76 centimetres  
6 by 6 by 48 in. = approximately 15 by 15 by 122 centimetres  
18 by 18 by 36 in. = approximately 46 by 46 by 91 centimetres

(Issued August 1977)

#### SUMMARY

To assess the durability of concrete and other materials used in concrete construction when exposed to natural weathering, the Corps of Engineers maintains severe-, mild-, moderate-, and nonweathering exposure stations at various locations in the United States. Specimens from actual structures and experimental specimens in which the amounts or kinds of components are varied are exposed until they fail or until testing is completed, whichever occurs first. The specimens are inspected periodically, and tested to determine their dynamic modulus of elasticity and pulse velocity. This report, in two volumes, describes the exposure stations, test methods used, the specimens, and lists test results to date. Volume 1 contains the active investigations, and volume 2 the completed investigations. These volumes are in loose-leaf form so that new or revised data can be added to volume 1, and completed studies can be transferred from volume 1 to volume 2. A preliminary report was prepared in June 1959, but the first complete edition was issued in June 1960. Revisions will be distributed annually.

(Reprinted Jan 1973)

INVESTIGATION OF PERFORMANCE OF CONCRETE AND CONCRETING  
MATERIALS EXPOSED TO NATURAL WEATHERING

PART I: INTRODUCTION

1. The ultimate test of the durability of concrete is its performance under the exposure conditions in which it is to serve. Although laboratory tests yield valuable indications of probable durability, the potential disrupting influences in nature are so numerous and variable that actual field exposures are highly desirable to assess the durability of concrete when exposed to natural weathering. To this end, exposure stations have been provided at several locations in the United States.

Severe-Weathering Station, Treat Island, Maine

2. The severe-weathering exposure station is located at Treat Island in Cobscook Bay near Eastport, Maine. This station has been in use since 1936 and is an ideal location for these tests, providing twice-daily tide reversals, together with severe winters. The specimens are installed at mean-tide elevation and the alternate conditions of immersion of the specimens in sea water, then exposure to cold air, provide numerous cycles of freezing-and-thawing of the concrete during the winter. The effect of the relatively cool summers is to lessen, in general, autogenous healing and chemical reactions in the concrete. The tidal range is a mean of about 18 ft,\* with a maximum of about 28 ft and a minimum of about 13 ft. Prior to September 1963, the half-tide exposure rack, on which most of the specimens are installed (the rest are on the beach), had a roof over it to eliminate differences in exposure due to sunlight and wind. In September 1963, the exposure-rack specimens were moved onto a new rack. This new rack contained no roof and the specimens are therefore exposed to sunlight and wind as are the beach specimens.

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\* A table of factors for converting British units of measurement to metric units is included on page vii.

3. In winter, the combination of air and water temperatures creates a condition in which specimens at the mean-tide elevation are thawed to a temperature of about 37 F when covered with water, and are frozen to temperatures as low as -10 F when exposed in air. A recording thermometer, the bulb of which is embedded in the center of a concrete specimen, records these temperatures. A cycle of freezing-and-thawing consists of the reduction of the temperature at the center of a concrete specimen to below 28 F, and its subsequent rise to above that figure. During an average winter, the specimens are subjected to over 100 cycles of freezing-and-thawing. In eleven winters, from 1960 to 1972, the number of annual cycles has ranged from 89 to 185, with the average being 145.

Mild-Weathering Station, St. Augustine, Fla.

4. The mild-weathering exposure station located in Salt-Run, off Anastasia Island near St. Augustine, Fla., was discontinued in November 1971. This station was established to provide information on the effects of sea water on concrete specimens apart from the effects of freezing-and-thawing. The specimens were installed at mean-tide elevation and, therefore, were subject to twice-daily tide reversals. The mean water temperature of about 70 F was found to be conducive to attack on concrete specimens by the dissolved salts in the sea water.

5. In September 1964, Hurricane "Dora" struck the St. Augustine area, breaching the bar between Salt-Run and the open sea and depositing a large quantity of sand on the exposure rack. In February 1966, an inspection party established that the continuing deposition of sand did not seriously alter the exposure conditions and no immediate action as a result of it was indicated. It became obvious, however, by mid-1971 that the sand deposits, which had by then become extensive, and the accelerating deterioration of the facility dictated its abandonment. A firm decision concerning the possible reestablishment of the mild-weathering station at another site has not yet been reached.

Moderate-Weathering Exposure Stations

6. The moderate-weathering exposure station was located outdoors at West Point, N. Y., from September 1940 to April 1942, then at Mt. Vernon, N. Y., from 1942 to 1946. Specimens for moderate exposure were stored outdoors at the U. S. Army Engineer Waterways Experiment Station Jackson Installation, Jackson, Miss., until October 1969. Here specimens were exposed to rain, occasionally ice or snow, cold, and strong sunlight, but were supported above the ground and allowed to drain freely. Moderate-weathering exposure was discontinued after October 1969.

Nonweathering Exposure Stations

7. A nonweathering exposure station was located in 1940 inside the laboratory buildings at West Point, N. Y., and later indoors at Mt. Vernon, N. Y., until 1946. Since that time, specimens for nonweathering exposure have been stored inside the Concrete Laboratory building at the Jackson Installation.

Composition of Sea Water at Treat Island,  
Maine, and St. Augustine, Fla.

Constituent	Parts per Million	
	Treat Island (Sampled in 1959)	Salt-Run (Sampled in 1958)
Total solids	35,275	38,770
Suspended solids	--	160
Dissolved solids	--	38,610
Calcium	370	430
Magnesium	1,175	1,340
Sodium	9,500	11,130
Potassium	370	450
Chloride	17,100	20,460
Sulfate	2,385	2,780

Test MethodsFrequency readings

8. The concrete specimens at all installations are subjected to test

for fundamental transverse frequency (Test Method CRD-C 18-59\*) at regular intervals\*\* during exposure, unless their shape or size prevents. The specimen is supported in a horizontal position at the nodes and caused to vibrate in its fundamental flexural mode. The resonant frequency is obtained by observing the maximum indication on a suitable meter as the applied frequency is varied. From this value together with the size, shape, and weight of the specimens, the dynamic modulus of elasticity (E) is determined. The moduli so determined are expressed as percentages of the initial dynamic modulus obtained at installation (%E). A specimen is considered as having failed if this percentage (%E) drops below 50 during the exposure.

#### Pulse velocity readings

9. The concrete specimens at all installations are subjected to pulse velocity tests (Test Method CRD-C 51-57) at regular intervals during exposure, unless their size or shape prevents. The test instrument measures the time of travel of a sound pulse through a concrete specimen. From the travel time and the path length, values for velocity of sound in concrete (V) are calculated. The square of the velocity thus determined is expressed as a percentage of the square of initial velocity obtained at installation (%V<sup>2</sup>). Example:

V<sub>o</sub> = velocity of sound in a certain specimen at installation.

V<sub>t</sub> = velocity of sound in this same specimen at a later date.

Therefore

$$\%V^2 \text{ (at time } t) = \frac{V_t^2}{V_o^2}$$

10. Pulse velocity readings on test specimens are taken through various paths depending upon specimen size, shape, and type of specimen. For example, one pulse velocity reading is taken through an 18- by 18- by 36-in. prism from the center of one 18- by 18-in. face to the center of

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\* U. S. Army Engineer Waterways Experiment Station, CE, Handbook for Concrete and Cement, Aug 1949 (with quarterly supplements), Vicksburg, Miss.

\*\* The specimens at St. Augustine were tested every two years; the specimens at all other stations are tested annually.

the 18- by 18-in. face on the other end; this provides a 36-in. path. This same path is used, if possible, each time the specimen is tested. A 2-ft cube is tested by transmitting the ultrasonic pulse from the center of one 2- by 2-ft face to the center of the opposite 2- by 2-ft face. Two such readings are taken for each 2-ft cube (paths normal to each other) and averaged to give the pulse velocity reading. The same two paths are used, if possible, each time the specimen is tested.

#### Visual inspection

11. All specimens are visually inspected periodically at all exposure stations to ascertain their condition. Those specimens not amenable to quantitative testing are inspected more thoroughly at times comparable to the testing periods to determine their condition and to permit comparisons of the durability of these specimens.

#### Criteria of failure

12. Specimens are regarded as having failed when they separate into pieces, when the %E is 50 or less, or when deterioration has progressed to such a point that reliable determinations of fundamental frequency and pulse velocity cannot be obtained. Specimens that have been broken in handling are so listed and not as "failed."

#### Specimen size

13. Test specimens of various sizes and shapes have been used from time to time as outdoor exposure specimens. In December 1963, however, it was specified in the Handbook for Concrete and Cement\* that specimens for outdoor exposure shall be 18 in. in height and depth, and 36 in. in length. The 18- by 18- by 36-in. prism was selected instead of a 2-ft cube because it (a) afforded a longer path length for pulse velocity readings, (b) contained less concrete and therefore weighed less, and (c) was more amenable to tests for fundamental transverse frequency. With a 36-in. path a smaller percentage of error is introduced into pulse velocity calculations because of minor variations in the measurement of path length than with a 24-in. path. A lighter specimen reduces handling and shipping costs and a specimen with a length-to-width ratio of 2 to 1 (prism) is less difficult

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\* U. S. Army Engineer Waterways Experiment Station, op. cit.

to excite in the fundamental flexural mode than a specimen with a length-to-width ratio of 1 to 1 (cube). In 1968, with the 18- by 18- by 36-in. prism as the outdoor exposure specimen and with enough exposure rack space available for the proper installation of a large number of prisms on their nodal points, large mass concrete specimens were tested for both fundamental flexural frequency and pulse velocity on a regular basis (see Section 39, Part II) for the first time at Treat Island, Maine.

#### Summary of Specimens

##### Treat Island exposure

14. Plate 1 gives a summary and the layout of the test specimens installed on the beach at Treat Island, Maine. The summary indexes each group of specimens on the beach by the section number given them in Part II of this report. Plate 2 gives the arrangement of test specimens on the exposure rack and also indexes each group by section number. Table 1 is a recapitulation of all specimens exposed at Treat Island and indexes each group by section number.

##### St. Augustine exposure

15. Plate 3 gives in detail the arrangement of test specimens on the exposure rack at St. Augustine, Fla., in November 1971 when that station was discontinued, and indexes each group by section number. Table 2 lists each group of test specimens exposed at St. Augustine and indexes them by section number.

(Revised August 1977)

Table 1

Recapitulation of Specimens Exposed at Treat Island, Maine

Location		Program of Investigation	Size and Kind	Specimens		Date Installed	Section No. in This Vol
Section	Row			No. Installed	No. Left		
Beach	2	Tensile Crack Specimens, Series A	7-ft-9-in.-long beams	82	0	Nov 1951	1
Beach	1	Tensile Crack Specimens, Series B	7-ft-9-in.-long beams	76	75	Nov 1954	2
Rack	9	Stewart Field Spheres	1-ft spheres	24	12	May 1954	3
Beach	2	Cement-Replacement Materials Investigation, Phase B	18- by 18- by 36-in. prisms	21	6	Dec 1953	4
Beach	2	Prestressed Concrete Program	4-1/2- by 9- by 81-in. beams	16	0	Oct 1958	6
Rack	3	Prestressed Concrete Program	3-1/2- by 4-1/2- by 16-in. beams	72	57	Oct 1958	6
Beach	2	Prestressed Concrete Program	10- by 16- by 96-in. beams	20	12	June 1961	6
Rack	4	Cement-Replacement Materials Investigation, Phase D	10- by 20-in. cores	75	21	Oct 1958	8
Beach	1	Cement-Replacement Materials Investigation, Phase D	2-ft cubes	20	4	Oct 1958	8
Rack	8	Passamaquoddy Project	5- by 5- by 60-in. columns	43	1	June 1936	9
Rack	5	Missouri River Division Program	3-1/2- by 4-1/2- by 16-in. beams	12	5	Sept 1963	10
Rack	5	Missouri River Division Program	3- by 4-1/2- by 16-in. beams	3	2	Nov 1965	10
Rack	5	Portland Blast-Furnace Slag Cement Investigation	3-1/2- by 4-1/2- by 16-in. beams	108	66	May 1956	11
Rack	3	Specimen Size-Frost Effects Investigation	3-1/2- by 4-1/2- by 16-in. beams	9	9	Dec 1968	12
Rack	2	Trumbull Pond Dam Prisms Investigation of 4-1/2-in. Aggregate Concrete	6- by 6- by 30-in. beams	3	3	Dec 1968	12
Rack	3		2-ft cubes	3	3	Dec 1968	12
Rack	2		18- by 18- by 36-in. prisms	3	3	Dec 1968	12
Rack	3		18- by 18- by 36-in. prisms	6	6	June 1972	13
Rack	2	Longtime Study, Waterways Experiment Station	18- by 18- by 36-in. prisms	12	5	Dec 1968	14
Rack	3	Mt. Morris Dam Cores	3-1/2- by 4-1/2- by 16-in. beams	198	196	May 1955	17
Rack	4	Air-Entraining Admixture Study	10-in.-diam by 18-in. cores	11	3	Oct 1949	22
Rack	2	Omaha District Aggregate Program	6- by 6- by 30-in. prisms	90	13	Nov 1944	25
Rack	2	Omaha District Aggregate Program	6- by 6- by 30-in. beams	6	3	Dec 1956	26
Rack	2	Kansas City District Aggregate Program	6- by 6- by 30-in. beams	3	0	Nov 1964	26
Rack	2			18	6	Jan 1958	27
Rack	2			18	1	May 1959	27
Rack	2			9	5	Nov 1962	27
Rack	2			9	5	Dec 1963	27
Rack	2			3	3	May 1969	27
Rack	2			3	3	July 1974	27
Rack	2	Eufaula Dam Aggregates Study	2-ft cubes	3	3	July 1974	27
Beach	1			3	3	Oct 1958	28
Rack	N wall			54	16	May 1957	30
Rack	N wall			27	0	May 1957	30
Rack	N wall	Nonmetallic Waterstop Investigation	Waterstop pieces	30	0	Nov 1957	30
Rack	N wall		Embedded waterstop pieces	15	0	Nov 1957	30
Rack	N wall		Waterstop pieces	2	0	Aug 1958	30
Rack	N wall		Embedded waterstop pieces	1	0	Aug 1958	30
Rack	5	Woven Plastic Test Program	13-in. squares	160	0	Nov 1963	31
Rack	5	Woven Plastic Test Program	13-in. squares	80	0	Apr 1967	31
Rack	5	Woven Plastic Test Program	13-in. squares	22	0	Mar 1970	31
Top of wharf		Membrane Curing Program	Box specimens	14	14	June 1946	34
Beach	2	Quality Aggregate Investigation	2-ft cubes	10	0	Nov 1962	35
Beach	A-1	Quality Aggregate Investigation	2-ft cubes	6	2	Dec 1963	35
Beach	2	Cement-Replacement Materials Investigation, Phase C	18- by 18- by 36-in. prisms	2	0	Nov 1962	36
Beach	2	Maximum Size of Coarse Aggregate Program		18	9	Dec 1963	37
Beach	A-1	Maximum Allowable Water-Cement Ratio Investigation		24	12	Dec 1964	38
Rack	1	Curing Investigation		56	56	June 1968	39
Rack	5	Investigation of Plastic Based Mortar Coatings	10- by 10- by 3-in. mortar-coated panels	8	8	July 1969	40
Rack	5	Investigation of Plastic Based Mortar Coatings	10- by 10- by 3-in. mortar-coated panels	8	8	Nov 1969	40
Rack	5	Investigation of Plastic Based Mortar Coatings	10- by 10- by 3-in. mortar-coated panels	16	16	Dec 1970	40
Rack	3	CERL Fibrous Concrete	3-1/2- by 4-1/2- by 16-in. beams	30	10	Jan 1975	5
Rack	4 & 6	WES Fibrous Concrete	9- by 9- by 45-in. beams	17	17	June 1975	7
Rack	5	WES Fibrous Concrete	6- by 6- by 30-in. beams	12	12	June 1975	7
Rack	5	WES Fibrous Concrete	6- by 6- by 36-in. beams	21	21	June 1975	7
Rack	9	Sulfur-Infiltrated Concrete	4- by 8-in. cylinders	18	18	Aug 1976	15
Rack	9	Sulfur-Infiltrated Concrete	3- by 6-in. cylinders	36	36	Aug 1976	15
Rack	6	Roller-Compacted Concrete	12- by 12- by 36-in. beams	6	6	July 1977	16
Rack	6	Charles River - Smelt Brook	6- by 6- by 24-in. beams	18	18	Aug 1976	18

-- Dashed lines in "Section" and "Row" columns indicate that these specimens are no longer on the exposure rack.

(Reprinted August 1977)

Table 2

Recapitulation of Specimens Exposed at St. Augustine, Fla.

Program of Investigation	Size and Kind	Specimens		Date	Sec. No. in This Vol
		No. In-stalled	No. Left		
Prestressed Concrete Program	4-1/2- by 9- by 81-in. beams	3	1	Oct 1959	6
Portland Blast-Furnace Slag Cement Investigation	3-1/2- by 4-1/2- by 16-in. beams	108	93	Aug 1956	11
	8-1/2- by 8-1/2- by 12-in. prisms	45	0	Aug 1956	11
Longtime Study Waterways Experiment Station	3-1/2- by 4-1/2- by 16-in. beams	198	195	Aug 1955	17
Alkali-Aggregate Reactivity Investigation	6- by 6- 30-in. beams	72	45	Aug 1955	29
	6- by 6- by 30-in. beams	36	30	Aug 1956	29
National Bureau of Standards Super-sulfate Cement Program	3- by 4- by 16-in. beams	27	19	Nov 1957	32

Note: Installation and testing of specimens at St. Augustine, Fla., was discontinued in November 1971.

PART II: PROGRAMS OF INVESTIGATION

16. A large number of investigational programs are in progress at the exposure stations. These programs involve varying numbers of specimens, installed at one or all exposure stations. The purposes of the different programs also have been varied. In general, they have constituted investigations of cements, aggregates, construction methods, admixtures, or combinations of these variables. The remainder of this report is devoted to a discussion of these test programs and to a presentation of the exposure records of the test specimens involved.

## PART II: PROGRAMS OF INVESTIGATION

15. A large number of investigational programs are in progress at the exposure stations. These programs involve varying numbers of specimens, installed at one or all exposure stations. The purposes of the different programs also have been varied. In general, they have constituted investigations of cements, aggregates, construction methods, admixtures, or combinations of these variables. The remainder of this report is devoted to a discussion of these test programs and to a presentation of the exposure records of the test specimens involved.

16. During the inspection of the Treat Island Exposure Station in July 1966, representatives of the Office, Chief of Engineers, recommended that the Treat Island exposure of test specimens in the following 13 programs be discontinued during FY 1967 provided the sponsoring agencies concurred.

<u>Program of Investigation</u>	<u>Section No. in this Volume</u>
National Bureau of Standards Program	12
Cement Durability Program	13
Rome Air Depot Program	14
Natural Cement Investigation	15
Resin Air-entraining Agent Program	16
Long-time Study, Waterways Experiment Station	17
Long-time Study, Portland Cement Association	18
Syracuse Air Base Beams	19
Field and Laboratory Correlation Program	20
Form Lining Investigation	21
Vacuum Treatment Investigation	23
Preplaced Aggregate Cores	24
Cooperative Study of Air-entrained Concrete	33

17. Eleven of the 13 programs listed above were discontinued in FY 1967. Subsequent correspondence has established that the Long-time Study, Waterways Experiment Station, Section 17, will continue active. The Cement Durability Study, Section 13, was discontinued in FY 1971. Data will no longer be collected from specimens at St. Augustine, Fla.

(Revised Aug 1965)

Section 1

Tensile Crack Specimens, Series A\*

In November 1951, 82 reinforced-concrete beams were installed at half-tide elevation on the beach at Treat Island. The purpose of this installation is to determine, for different types of reinforcing steel, the relation between the degree of tensile stress in the steel and the resistance of reinforced concrete to severe natural weathering.

The beams were 7 ft 9 in. long and were made of concrete with a nominal compressive strength of 3500 psi at 28 days age. Air-entrained ( $4\frac{1}{2} \pm 1\frac{1}{2}\%$ ) and nonair-entrained concrete were used. Seventy-four beams were reinforced with rail-steel bars, of which 64 had deformations conforming to ASTM Designation A 305-50T, and the other 10 had old-style deformations. Eight beams were reinforced with billet-steel bars having deformations conforming to ASTM Designation A 305-50T. Coverage over the steel was either  $\frac{3}{4}$  in. or 2 in., and bars were placed in either bottom or top position when the concrete was placed. Aggregates were a manufactured limestone sand and a crushed limestone coarse aggregate (1-in. maximum size). Type II cement was used, with the cement factors ranging from 5.20 (for the plain concrete) to 5.35 (for the air-entrained concrete) bags per cu yd. The air-entraining agent was admixture P. The water-cement ratio (by weight) used was 0.60 for the air-entrained concrete and 0.70 for the plain concrete.

Seventy-two beams were yoked and stressed by third-point loading; loads ranged from 20,000 to 50,000 psi. The remaining 10 beams were controls.

Table 1-TC-A lists these specimens and gives their exposure record along with other pertinent information.

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\* See U. S. Army Engineer Waterways Experiment Station, CE, Tensile Crack Exposure Tests, by T. B. Kennedy, and Tensile Crack Exposure Tests, Results of Tests of Reinforced Concrete Beams, 1955-1963, by E. C. Roshore, Technical Memorandum No. 6-412, Reports 1 and 2 (Vicksburg, Miss., July 1955 and November 1964).

(Revised Sept 1968)

Table 1-TC-A

Section 1

**Record of Observation and Testing of Large-Beam Tensile Crack Specimens,  
Series A, 1951- (Installed Nov 1951)**

1951-1956 Readings																Beach Row 2	
Beam No.	Nominal Stress psi	Steel Position*	Cover in.	Type** Steel Deformation	Plain or Air-entr Concrete	0 Cycl	101 Cycl	186 Cycles, 1953	Pulse		297 Cycles 1954		442 Cycles 1955		609 Cycles 1956		
						1951	1952	Condi- tion	Veloc- ity fps	%V <sup>2</sup>	Condi- tion	%V <sup>2</sup>	Condi- tion	%V <sup>2</sup>	Condi- tion	%V <sup>2</sup>	
1	20,000	T	3/4	RS	Air	100	93	93	12,345	100	83	143	76	153	64	157	
2	20,000	T	3/4	RS	Air	100	96	91	13,425	100	82	129	91	131	77	135	
3	20,000	B	3/4	RS	Air	100	96	95	14,965	100	89	86	78	102	69	105	
4	20,000	B	3/4	RS	Air	100	93	85	15,505	100	84	91	91	95	76	98	
5	30,000	T	3/4	RS	Air	100	93	98	12,120	100	95	82	92	102	77	138	
6	30,000	T	3/4	RS	Air	100	93	89	15,230	100	91	60	89	49	84	107	
7	30,000	B	3/4	RS	Air	100	96	100	12,245	100	91	124	79	144	47	149	
8	30,000	B	3/4	RS	Air	100	96	95	13,605	100	91	94	94	116	82	124	
9	40,000	T	3/4	RS	Air	100	89	85	14,600	100	82	100	94	112	78	113	
10	40,000	T	3/4	RS	Air	100	93	100	13,455	100	92	104	89	112	76	130	
11	40,000	B	3/4	RS	Air	100	89	85	13,130	100	82	79	91	70	70	134	
12	40,000	B	3/4	RS	Air	100	93	98	13,335	100	94	80	89	113	80	131	
13	50,000	T	3/4	RS	Air	100	96	100	13,575	100	95	77	86	75	78	121	
14	50,000	T	3/4	RS	Air	100	93	88	12,685	100	80	82	89	126	80	151	
15	50,000	B	3/4	RS	Air	100	93	95	12,000	100	89	100	86	100	85	163	
16	50,000	B	3/4	RS	Air	100	93	83	12,550	100	82	92	92	92	86	147	
17	None	B	3/4	RS	Air	100	96	90	15,190	100	87	94	89	104	82	96	
18	None	B	3/4	RS	Air	100	96	100	15,190	100	95	96	100	99	90	90	
19	20,000	T	3/4	RS	Plain	100	54	25F	10,150	100							
20	20,000	B	3/4	RS	Plain	100	26	3F									
21	20,000	B	3/4	RS	Plain	100	87	81	16,090	100	60	--	F				
22	20,000	B	3/4	RS	Plain	100	78	58	15,465	100	23	--	F				
23	20,000	B	3/4	OS	Plain	100	53	10F									
24	20,000	B	3/4	OS	Plain	100	83	57	13,305	100	F						
25	30,000	T	3/4	RS	Plain	100	61	20	--	--	F						
26	30,000	T	3/4	RS	Plain	100	25	F									
27	30,000	B	3/4	RS	Plain	100	86	81	14,390	100	81	--	F				
28	30,000	B	3/4	RS	Plain	100	83	28	14,020	100	3F						
29	30,000	B	3/4	OS	Plain	100	F										
30	30,000	B	3/4	OS	Plain	100	75	84	13,795	100	F						
31	40,000	T	3/4	RS	Plain	100	8F										
32	40,000	T	3/4	RS	Plain	100	F										
33	40,000	T	3/4	RS	Plain	100	71	68	14,495	100	32	--	F				
34	40,000	B	3/4	RS	Plain	100	50	27	14,530	100	F						
35	40,000	B	3/4	RS	Plain	100	25	5F									
36	40,000	B	3/4	RS	Plain	100	93	42	13,575	100	F						
37	50,000	T	3/4	RS	Plain	100	25	8F									
38	50,000	T	3/4	RS	Plain	100	64	33	12,765	100	F						
39	50,000	T	3/4	RS	Plain	100	64	F									
40	50,000	B	3/4	RS	Plain	100	25	F									
41	50,000	B	3/4	RS	Plain	100	83	40	13,795	100	23	--	F				
42	50,000	B	3/4	RS	Plain	100	32	22	13,425	100	F						
43	None	T	3/4	RS	Plain	100	58	57	15,915	100	35	--	17	--	F		
44	None	T	3/4	RS	Plain	100	50	32	12,605	100	17	--	F				
45	None	B	3/4	RS	Plain	100	61	46	10,100	100	20	--	F				
46	None	B	3/4	OS	Plain	100	64	43	9,315	100	8	--	F				
47	20,000	T	2	RS	Plain	100	70	54	11,740	100	20	--	F				
48	20,000	T	2	RS	Plain	100	50	27	--	--	F						
49	20,000	B	2	RS	Plain	100	75	68	13,245	100	23	--	F				
50	20,000	B	2	RS	Plain	100	92	46	12,795	100	F						
51	20,000	B	2	OS	Plain	100	57	F									
52	20,000	B	2	OS	Plain	100	75	44	12,930	100	F						
53	30,000	B	2	RS	Plain	100	50	29	--	--	F						
54	30,000	B	2	RS	Plain	100	46	F									
55	30,000	B	2	RS	Plain	100	75	41	9,130	100	F						
56	30,000	B	2	RS	Plain	100	39	F									
57	30,000	B	2	OS	Plain	100	87	46	13,605	100	F						
58	30,000	B	2	OS	Plain	100	F										
59	40,000	T	2	RS	Plain	100	67	66	13,085	100	39	--	F				
60	40,000	T	2	RS	Plain	100	58	46	10,990	100	F						

(Continued)

Note: Condition ratings are expressed numerically; i.e., 100 denotes perfect condition, F denotes specimen failed.

-- Dashed lines in the "Pulse Veloc" or "%V<sup>2</sup>" columns indicate that a pulse velocity reading was not taken because of the poor condition of the beam.

\* T = near top of beam.

B = near bottom of beam.

\*\* RS = rail steel with deformations conforming to ASTM Designation A 305-50T.

OS = old style (does not meet ASTM Designation A 305-50T deformation requirements).

BS = billet-steel with deformations conforming to ASTM Designation A 305-50T.

(Sheet 1)

(Revised Sept 1968)

Table 1-TC-A (Continued)

Section 1

Beach Row 2

Beam No.	Nominal Stress psi	Steel Position	Cover in.	Type Steel Deformation	Plain or Air-entr Concrete	1951-1956 Readings									
						0 Cycl 1951	101 Cycl 1952	186 Cycles, 1953		297 Cycles 1954	442 Cycles 1955	609 Cycles 1956			
						Condi- tion	Condi- tion	Condi- tion	Pulse Veloc fps	$\frac{1}{2}V^2$	Condi- tion	$\frac{1}{2}V^2$	Condi- tion	$\frac{1}{2}V^2$	Condi- tion
61	40,000	T	2	RS	Plain	100	F								
62	40,000	B	2	RS	Plain	100	43	27	9,330	100	F	--	F		
63	40,000	B	2	RS	Plain	100	88	64	14,220	100	37	--	F		
64	40,000	B	2	RS	Plain	100	61	25	12,765	100	F				
65	50,000	T	2	RS	Plain	100	F								
66	50,000	T	2	RS	Plain	100	50	5	--	--	F	--	F		
67	50,000	T	2	RS	Plain	100	68	52	13,515	100	42	--	F		
68	50,000	B	2	RS	Plain	100	87	83	14,150	100	80	114	F		
69	50,000	B	2	RS	Plain	100	67	58	12,765	100	34	--	F		
70	50,000	B	2	RS	Plain	100	42	29	10,850	100	23	--	F		
71	None	T	2	RS	Plain	100	58	41	12,850	100	30	--	14	--	F
72	None	T	2	RS	Plain	100	68	59	12,295	100	47	--	17	--	F
73	None	B	2	RS	Plain	100	29	25	10,325	100	9	--	F		
74	None	B	2	OS	Plain	100	29	23	--	--	8	--	F		
75	20,000	B	3/4	BS	Plain	100	93	81	13,485	100	30	--	F		
76	20,000	B	3/4	BS	Air	100	96	100	14,780	100	91	--	F		
77	20,000	B	2	BS	Plain	100	86	59	13,160	100	31	--	F		
78	20,000	B	2	BS	Air	100	96	100	14,495	100	94	--	F		
79	30,000	B	3/4	BS	Plain	100	89	40	12,295	100	F				
80	30,000	B	3/4	BS	Air	100	93	93	11,110	100	87	--	F		
81	30,000	B	2	BS	Plain	100	89	65	13,575	100	28	--	F		
82	30,000	B	2	BS	Air	100	93	100	11,930	100	89	--	F		

Beach Row 2

						1957-1962 Readings										each row	
						753 Cycles		824 Cycles		974 Cycles		1045 Cycles		1186 Cycles		1275 Cycles	
						1957		1958		1959†		1960		1961		1962	
						Condi- tion	$\frac{1}{2}V^2$	Condi- tion	$\frac{1}{2}V^2$	Condi- tion	$\frac{1}{2}V^2$	Condi- tion	$\frac{1}{2}V^2$	Condi- tion	$\frac{1}{2}V^2$	Condi- tion	$\frac{1}{2}V^2$
1	20,000	T	3/4	RS-"A"	Air	76	143	70	144	26	142	26	129	29	155	27	145
2	20,000	T	3/4	RS-"A"	Air	71	127	65	128	55	114	55	125	48	139	50	127
3	20,000	B	3/4	RS-"A"	Air	73	105	79	106	26	104	26	104	32	105	30	98
4	20,000	B	3/4	RS-"B"	Air	64	94	72	95	46	91	46	97	44	99	44	96
5	30,000	T	3/4	RS-"B"	Air	79	152	80	154	63	147	63	151	61	158	60	153
6	30,000	T	3/4	RS-"B"	Air	80	92	78	95	73	81	73	85	63	102	60	90
7	30,000	B	3/4	RS-"B"	Air	32	150	35	149	25	137	25	152	34	157	32	154
8	30,000	B	3/4	RS-"B"	Air	76	117	71	118	75	107	75	126	62	112	60	108
9	40,000	T	3/4	RS-"A"	Air	77	108	75	109	66	102	66	103	64	105	63	98
10	40,000	T	3/4	RS-"A"	Air	81	---	79	135	67	126	67	120	66	120	63	110
11	40,000	B	3/4	RS-"A"	Air	64	126	57	127	51	108	51	114	50	141	50	120
12	40,000	B	3/4	RS-"A"	Air	80	131	81	126	75	111	75	118	61	132	59	118
13	50,000	T	3/4	RS-"B"	Air	74	115	81	120	59	118	59	82	51	127	48	108
14	50,000	T	3/4	RS-"B"	Air	65	140	70	144	60	94	60	91	60	129	58	121
15	50,000	B	3/4	RS-"B"	Air	78	169	69	149	59	104	59	138	57	134	57	118
16	50,000	B	3/4	RS-"B"	Air	76	143	84	139	57	104	57	144	55	143	56	143
17	None	B	3/4	RS-"A"	Air	71	99	74	100	66	91	††					
18	None	B	3/4	RS-"A"	Air	79	98	73	100	67	93	67	90	56	88	54	182

(Continued)

† Hardware on all remaining loaded specimens was replaced in May 1959. The condition of these remaining specimens is adjudged either annually or biennially by a panel of observers and is expressed numerically.

†† Exposure testing on this beam was discontinued in January 1960, as a piece of steel had to be removed from it for additional testing.

(Sheet 2)

(Revised August 1977)

Table 1-TC-A (Continued)

Section 1

Beach Row 2

1963-1967 Readings											1965 Cycles 1967						
											$\%V^2$						
Beam No.	Nominal Stress psi	Steel Position	Cover in.	Type Steel Deformation	Plain or Air-entr Concrete	1381 Cycles		1516 Cycles		1679 Cycles		1809 Cycles		Condi- tion	Be- fore Un- load- ing	Not Loaded	After Re- load- ing
						1963	$\%V^2$	1964	$\%V^2$	1965	$\%V^2$	1966	$\%V^2$				
1	20,000	T	3/4	RS-"A"	Air	29	103	26	111	*	86	24	**	*	100		88
2	20,000	T	3/4	RS-"A"	Air	46	90	44	84		70	39			89		66
3	20,000	B	3/4	RS-"A"	Air	39	70	30	69		62	28			68		57
4	20,000	B	3/4	RS-"A"	Air	46	65	44	63		46	42			64		56
5	30,000	T	3/4	RS-"B"	Air	57	107	54	103		70	50			82		57
6	30,000	T	3/4	RS-"B"	Air	71	67	60	57		41	61			47		23
7	30,000	B	3/4	RS-"B"	Air	32	104	31	95		97	31			98		49
8	30,000	B	3/4	RS-"B"	Air	59	85	63	78		52	62			83		54
9	40,000	T	3/4	RS-"A"	Air	60	91	63	65		42	62			48		49
10	40,000	T	3/4	RS-"A"	Air	67	98	66	71		52	60			56		49
11	40,000	B	3/4	RS-"A"	Air	51	91	50	81		57	46			71		44
12	40,000	B	3/4	RS-"A"	Air	61	86	59	83		60	55			66		49
13	50,000	T	3/4	RS-"B"	Air	48	78	51	85		57	34			70		45
14	50,000	T	3/4	RS-"B"	Air	60	88	60	90		63	58			60		19
15	50,000	B	3/4	RS-"B"	Air	56	109	58	60		51	56			82		63
16	50,000	B	3/4	RS-"B"	Air	55	100	55	78		51	55			78		56
18	None	B	3/4	RS-"A"	Air	65	81	55	66		52	60				52	

1968-1973 Readings											2150 Cycles				2304 Cycles				2457 Cycles				2626 Cycles				2783 Cycles				2923 Cycles			
											1968				1969				1970				1971				1972				1973			
Beam No.	Nominal Stress psi	Steel Position	Cover in.	Type Steel Deformation	Plain or Air-entr Concrete	1968		1969		1970		1971		1972		1973		1970		1971		1972		1973		1972		1973		1973				
						Condi- tion	$\%V^2$	Condi- tion	$\%V^2$	Condi- tion	$\%V^2$	Condi- tion	$\%V^2$	Condi- tion	$\%V^2$	Condi- tion	$\%V^2$	Condi- tion	$\%V^2$	Condi- tion	$\%V^2$	Condi- tion	$\%V^2$	Condi- tion	$\%V^2$	Condi- tion	$\%V^2$	Condi- tion	$\%V^2$	Condi- tion	$\%V^2$	Condi- tion	$\%V^2$	
1	20,000	T	3/4	RS-"A"	Air	24	84	29	63	29	56	26	30	28	31	24	**																	
2	20,000	T	3/4	RS-"A"	Air	39	50	46	36	46	38	29	23	42	30	17																		
3	20,000	B	3/4	RS-"A"	Air	28	58	28	47	31	36	28	34	28	54	29																		
4	20,000	B	3/4	RS-"A"	Air	37	49	37	45	38	32	16	32	30	27	30																		
5	30,000	T	3/4	RS-"B"	Air	50	87	54	44	54	64	54	51	54	40	52																		
6	30,000	T	3/4	RS-"B"	Air	57	40	56	23	57	37	52	30	47	20	91																		
7	30,000	B	3/4	RS-"B"	Air	31	49	33	46	33	66	33	50	32	38	31																		
8	30,000	B	3/4	RS-"B"	Air	55	47	55	34	61	54	48	41	50	29	44																		
9	40,000	T	3/4	RS-"A"	Air	56	48	59	21	59	30	50	24	22	##	21																		
10	40,000	T	3/4	RS-"A"	Air	47	49	50	26	62	38	22	29	22	##	72																		
11	40,000	B	3/4	RS-"A"	Air	46	68	47	24	49	30	45	25	42	25	46																		
12	40,000	B	3/4	RS-"A"	Air	50	62	51	22	58	32	45	29	51	31	46																		
13	50,000	T	3/4	RS-"B"	Air	28	51	22	37	19	55	18	40	17	28	16																		
14	50,000	T	3/4	RS-"B"	Air	58	63	58	37	58	53	55	25	58	25	50																		
15	50,000	B	3/4	RS-"B"	Air	54	60	51	26	56	34	50	37	34	29	Failed																		
16	50,000	B	3/4	RS-"B"	Air	53	57	54	26	52	36	53	36	50	32	Damaged																		
18	None	B	3/4	RS-"A"	Air	55	49	55	22	53	34	55	27	55	36																			

1974- Readings											3059 Cycles				3171 Cycles				
											1974				1975				
Beam No.	Nominal Stress psi	Steel Position	Cover in.	Type Steel Deformation	Plain or Air-entr Concrete	1974		1975		1975		1975		1975		1975		1975	
						Condition	$\%V^2$	Condition	$\%V^2$	Condition	$\%V^2$	Condition	$\%V^2$	Condition	$\%V^2$	Condition	$\%V^2$		
1	20,000	T	3/4	RS-"A"	Air	26	**	23	30										
2	20,000	T	3/4	RS-"A"	Air	31		20	30										
3	20,000	B	3/4	RS-"A"	Air														
4	20,000	B	3/4	RS-"A"	Air	Unloaded													
5	30,000	T	3/4	RS-"B"	Air	52		51	45										
6	30,000	T	3/4	RS-"B"	Air	44		40	47										
7	30,000	B	3/4	RS-"B"	Air	33		30	40										
8	30,000	B	3/4	RS-"B"	Air	50		30	57										
9	40,000	T	3/4	RS-"A"	Air														
10	40,000	T	3/4	RS-"A"	Air	Unloaded													
11	40,000	B	3/4	RS-"A"	Air	43		41	62										
12	40,000	B	3/4	RS-"A"	Air	49		45	52										
13	50,000	T	3/4	RS-"B"	Air														
14	50,000	T	3/4	RS-"B"	Air	Unloaded													
15	50,000	B	3/4	RS-"B"	Air														
16	50,000	B	3/4	RS-"B"	Air	Damaged													
18	None	B	3/4	RS-"A"	Air														

NOTE: All beams returned to laboratory for testing.

\* In 1965 and 1967 the condition of specimens was not rated by panel of observers.

\*\* Satisfactory pulse velocity readings were not obtained in 1966, 1973, and 1974 due to malfunction of testing equipment.

§ Channel iron on all loaded beams was replaced with stainless steel channel in June 1967. Pulse velocity readings were therefore taken on all loaded beams before unloading and after reloading with stainless steel channel.

# Some pulse velocity readings obtained in 1969 and 1970 are not believed to be valid due to the power limitations of the test equipment; these  $\%V^2$  readings are therefore questionable.

## Unable to obtain satisfactory reading.

|| Returned to laboratory.

(Sheet 3)

Tensile Crack Specimens, Series B\*

In November 1954, 76 reinforced-concrete beams were installed at half-tide elevation on the beach at Treat Island. The purpose of this installation is to compare the relative resistance to weathering of highly stressed reinforced-concrete beams containing (a) reinforcement bars deformed to conform to ASTM Designation A 305-50T, and (b) bars with old-style deformations.

The beams were 7 ft 9 in. long and were made of air-entrained concrete with a nominal compressive strength of 3500 psi at 28 days age. All of the beams were reinforced with rail-steel bars; the bars in half of the beams had deformations conforming to ASTM Designation A 305-50T, and those in the other half had old-style deformations. All steel was placed with a nominal cover of 2 in. from either the top or bottom of the beam, depending on whether the bar was in the top or the bottom of the mold when the concrete was placed. Aggregates were a manufactured limestone sand and a crushed limestone coarse aggregate (1-in. maximum size). Type II cement was used, with the cement factors ranging from 5.25 to 5.38 bags per cu yd. The air-entraining admixture was admixture R; the water-cement ratio (by weight) was 0.58; the air content ranged from 5.0 to 7.0 per cent.

Sixty-four of the beams were yoked and stressed by third-point loadings; the loads ranged from 20,000 to 50,000 psi. The remaining 12 beams were controls and were not loaded.

Table 1-TC-B lists these specimens and gives their exposure record along with other pertinent information.

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\* See report to Office, Chief of Engineers, Tensile Crack Exposure Tests - Progress Report - Second Series of Tests (July 1955).

U. S. Army Engineer Waterways Experiment Station, CE, Tensile Crack Exposure Tests; Results of Tests of Reinforced Concrete Beams, 1955-1963, by E. C. Roshore, Technical Memorandum No. 6-412, Report No. 2 (Vicksburg, Miss., November 1964).

(Revised Aug 1965)

Table 1-TC-B

Section 2

## Record of Observation and Testing of Large-beam Tensile Crack Specimens,

Series B, 1954- (Installed Nov 1954)

Beach Row 1

Beam No.	Nominal Stress psi	Steel Position*	Type** Steel Deformation	1954-1958 Readings									
				0 Cycles, 1954			143 Cycles 1955		310 Cycles 1956		454 Cycles, 1957		
				Condi- tion	Pulse Veloc fps	$\%V^2$	Condi- tion	Condi- tion	Condi- tion	$\%V^2$	Max Crack Width† 1/1000 in.	Condi- tion	$\%V^2$
83	20,000	B	A-305	Sound	10,890	100	100	91	87	173	10	88	173
84	20,000	B	A-305	Sound	11,150	100	100	91	88	168	5	84	170
85	20,000	B	OS	Sound	11,720	100	100	90	84	157	10	83	153
86	20,000	B	OS	Sound	11,470	100	100	87	82	170	10	84	155
87	20,000	B	A-305	Sound	10,640	100	100	82	74	171	5	77	183
88	20,000	B	A-305	Sound	10,470	100	100	84	76	175	10	77	200
89	20,000	B	OS	Sound	11,255	100	100	84	87	162	10	87	167
90	20,000	B	OS	Sound	11,300	100	100	83	83	160	10	82	169
91	30,000	B	A-305	Sound	11,540	100	93	90	79	146	10	76	151
92	30,000	B	A-305	Sound	11,540	100	100	90	82	161	10	81	166
93	30,000	B	OS	Sound	12,120	100	100	87	80	151	15	80	152
94	30,000	B	OS	Sound	11,605	100	100	87	82	145	20	80	169
95	30,000	B	A-305	Sound	11,905	100	100	92	84	154	10	80	156
96	30,000	B	A-305	Sound	11,195	100	100	90	86	162	10	80	174
97	30,000	B	OS	Sound	11,385	100	100	86	86	152	15	86	154
98	30,000	B	OS	Sound	11,385	100	100	92	85	149	20	87	159
99	40,000	B	A-305	Sound	10,290	100	100	88	87	190	15	84	202
100	40,000	B	A-305	Sound	10,435	100	100	88	87	190	10	88	188
101	40,000	B	OS	Sound	10,400	100	98	82	82	195	15	79	191
102	40,000	B	OS	Sound	10,455	100	100	84	82	167	20	81	203
103	40,000	B	A-305	Sound	8,915	100	95	83	80	228	10	76	246
104	40,000	B	A-305	Sound	8,585	100	94	82	78	248	25	73	269
105	40,000	B	OS	Sound	9,230	100	100	86	91	246	10	92	237
106	40,000	B	OS	Sound	9,435	100	100	80	80	236	25	84	238
107	50,000	B	A-305	Sound	10,310	100	100	86	80	195	15	80	191
108	50,000	B	A-305	Sound	11,385	100	98	86	77	147	20	80	156
109	50,000	B	OS	Sound	8,915	100	91	74	72	274	20	80	273
110	50,000	B	OS	Sound	10,170	100	92	74	73	199	25	76	201
111	50,000	B	A-305	Sound	9,130	100	99	79	74	251	20	76	252
112	50,000	B	A-305	Sound	9,160	100	100	86	86	242	20	86	255
113	50,000	B	OS	Sound	8,850	100	93	70	64	243	25	69	279
114	50,000	B	OS	Sound	8,525	100	100	77	77	250	30	76	269
115	None	B	A-305	Sound	12,985	100	96	86	84	115	0	82	122
116	None	B	A-305	Sound	13,015	100	100	88	84	110	0	80	111
117	None	B	A-305	Sound	13,245	100	100	94	93	114	10	90	116
118	None	B	OS	Sound	13,250	100	98	76	65	111	0	69	119
119	None	B	OS	Sound	13,130	100	100	91	90	119	0	86	112
120	None	B	OS	Sound	13,185	100	100	88	89	115	0	85	115
121	20,000	T	A-305	Sound	9,600	100	96	87	80	218	35	81	234
122	20,000	T	A-305	Sound	9,570	100	96	87	86	237	10	85	225
123	20,000	T	OS	Sound	9,870	100	100	86	86	205	10	76	229
124	20,000	T	OS	Sound	9,675	100	100	84	86	216	10	73	231
125	20,000	T	A-305	Sound	12,960	100	100	86	86	120	15	86	131
126	20,000	T	A-305	Sound	13,160	100	100	79	80	122	35	87	127
127	20,000	T	OS	Sound	13,365	100	100	94	90	132	10	93	122
128	20,000	T	OS	Sound	13,015	100	100	92	90	135	10	92	132
129	30,000	T	A-305	Sound	9,755	100	97	83	75	224	15	74	227
130	30,000	T	A-305	Sound	9,820	100	98	83	83	230	20	77	230
131	30,000	T	OS	Sound	11,675	100	96	81	76	136	20	75	155
132	30,000	T	OS	Sound	11,675	100	96	77	76	159	30	80	150
133	30,000	T	A-305	Sound	13,070	100	100	88	88	115	10	88	125
134	30,000	T	A-305	Sound	12,820	100	100	88	88	120	15	87	130
135	30,000	T	OS	Sound	12,875	100	93	87	78	141	15	80	142
136	30,000	T	OS	Sound	11,340	100	95	86	80	158	10	81	149
137	40,000	T	A-305	Sound	10,510	100	91	88	70	148	20	76	127

(Continued)

\* T = near top of beam.

B = near bottom of beam.

\*\* A-305 = deformation conforming to ASTM Designation A 305-50T.

OS = old style deformations (does not meet ASTM Designation A 305-50T deformation requirements).

† From 1956, the widths of cracks in these specimens were measured with a measuring magnifier (least reading = 0.005 in.).

(Sheet 1)

(Revised Aug 1965)

Table 1-TC-B (Continued)

Section 2

Beach Row 1

1954-1958 Readings															Beach Row 1
Beam No.	Nominal Stress psi	Steel Position	Type Steel Deformation	0 Cycles, 1954			143 Cycles 1955	310 Cycles 1956	454 Cycles, 1957			525 Cycles, 1958			
				Condi- tion	Pulse Veloc fps	W <sup>2</sup>	Condi- tion	Condi- tion	Condi- tion	W <sup>2</sup>	Max Crack Width		Condi- tion	W <sup>2</sup>	Max Crack Width
											1/1000 in.	1/1000 in.			
138	40,000	T	A-305	100	10,490	100	92	89	74	177	25	78	182	25	
139	40,000	T	OS	100	12,095	100	88	78	72	132	15	72	150	15	
140	40,000	T	OS	100	12,225	100	90	76	71	129	15	74	148	15	
141	40,000	T	A-305	100	9,275	100	99	84	78	249	15	70	241	20	
142	40,000	T	A-305	100	9,570	100	100	85	76	228	15	78	227	20	
143	40,000	T	OS	100	9,375	100	94	82	76	224	25	84	234	25	
144	40,000	T	OS	100	9,390	100	95	86	84	231	40	84	238	40	
145	50,000	T	A-305	100	9,435	100	96	82	82	243	40	84	253	40	
146	50,000	T	A-305	100	9,345	100	94	81	78	238	30	81	255	30	
147	50,000	T	OS	100	8,970	100	86	66	68	272	85	72	249	85	
148	50,000	T	OS	100	8,900	100	82	67	67	260	75	70	260	75	
149	50,000	T	A-305	100	9,105	100	99	83	78	225	40	88	235	40	
150	50,000	T	A-305	100	9,175	100	100	82	82	235	25	86	259	30	
151	50,000	T	OS	100	11,130	100	92	80	76	180	15	72	164	15	
152	50,000	T	OS	100	10,655	100	88	78	72	195	25	74	181	25	
153	None	T	A-305	100	12,475	100	94	86	74	120	0	72	121	0	
154	None	T	A-305	100	12,795	100	100	92	87	117	0	88	132	0	
155	None	T	A-305	100	12,875	100	100	90	86	115	0	80	120	0	
156	None	T	OS	100	13,045	100	100	91	90	120	0	82	118	0	
157	None	T	OS	100	12,630	100	98	86	80	120	0	75	124	0	
158	None	T	OS	100	12,710	100	99	78	61	120	10	70	119	15	

Beach Row 1

				1959-1961 Readings								
				675 Cycles, 1959			746 Cycles, 1960			887 Cycles, 1961		
				Condition	$\%V^2$	Max Crack Width 1/1000 in.	Condition††	$\%V^2$	Max Crack Width 1/1000 in.	Condition	$\%V^2$	Max Crack Width 1/1000 in.
83	20,000	B	A-305	84	161	15	84	180	10	75	192	10
84	20,000	B	A-305	86	161	20	86	159	10	77	179	10
85	20,000	B	OS	91	143	15	91	158	10	79	146	10
86	20,000	B	OS	82	150	15	82	137	10	68	172	10
87	20,000	B	A-305	72	176	15	72	128	10	61	187	10
88	20,000	B	A-305	73	181	10	73	133	10	68	174	10
89	20,000	B	OS	86	160	15	86	152	10	73	153	10
90	20,000	B	OS	78	158	10	78	147	10	74	151	10
91	30,000	B	A-305	80	140	15	80	107	10	71	155	10
92	30,000	B	A-305	82	154	10	82	162	10	67	159	10
93	30,000	B	OS	80	152	30	80	108	20	71	151	15
94	30,000	B	OS	75	158	25	75	113	30	69	158	25
95	30,000	B	A-305	85	144	25	85	142	15	79	159	10
96	30,000	B	A-305	85	162	20	85	167	15	69	168	15
97	30,000	B	OS	78	147	20	78	133	10	65	168	10
98	30,000	B	OS	78	145	20	78	151	15	63	164	10
99	40,000	B	A-305	77	189	25	77	174	15	62	215	15
100	40,000	B	A-305	78	179	25	78	167	15	70	205	10
101	40,000	B	OS	70	181	35	70	135	30	65	177	25
102	40,000	B	OS	68	188	45	68	137	20	67	190	15
103	40,000	B	A-305	72	233	25	72	197	15	61	224	15
104	40,000	B	A-305	66	250	25	66	267	20	65	243	20
105	40,000	B	OS	86	224	20	86	165	15	72	219	15
106	40,000	B	OS	66	223	20	66	158	15	56	253	15
107	50,000	B	A-305	68	180	20	68	132	15	53	199	15
108	50,000	B	A-305	75	146	25	75	107	20	58	145	15
109	50,000	B	OS	68	254	35	68	228	25	67	221	25
110	50,000	B	OS	57	192	35	57	169	30	56	191	25
111	50,000	B	A-305	59	243	30	59	167	20	58	226	20
112	50,000	B	A-305	77	237	30	77	168	20	66	228	15

(Continued)

†† Hardware was replaced on all loaded specimens in May 1959. The condition of these specimens is adjudged either annually or biennially by a panel of observers during the formal inspection, and is expressed numerically, i.e. 100 denotes perfect condition.

(Sheet 2)

(Revised Aug 1965)

Table 1-TC-B (Continued)

Section 2

Beach Row 1

Beam No.	Nominal Stress psi	Steel Position	Type Steel Deformation	675 Cycles, 1959			1959-1961 Readings			887 Cycles, 1961		
				Condition	Max Crack Width		Condition	Max Crack Width		Condition	Max Crack Width	
					$\delta V^2$	1/1000 in.		$\delta V^2$	1/1000 in.		$\delta V^2$	1/1000 in.
113	50,000	B	OS	62	238	30	62	173	25	50	229	20
114	50,000	B	OS	64	255	35	64	192	25	54	265	20
115	None	B	A-305	78	113	0	78	112	0	69	131	0
116	None	B	A-305	80	107	0	80	114	0	74	115	5
117	None	B	A-305	80	105	20	80	109	10	68	117	10
118	None	B	OS	55	111	0	55	112	0	46	104	0
119	None	B	OS	70	104	0	70	111	0	67	123	0
120	None	B	OS	59	105	0	59	112	0	59	119	0
121	20,000	T	A-305	80	221	15	80	165	10	77	230	10
122	20,000	T	A-305	82	213	15	82	156	10	70	226	10
123	20,000	T	OS	77	216	20	77	158	10	61	231	10
124	20,000	T	OS	82	217	20	82	196	15	65	230	10
125	20,000	T	A-305	70	124	20	70	89	10	68	124	10
126	20,000	T	A-305	77	118	10	77	84	10	77	120	10
127	20,000	T	OS	86	121	15	86	130	10	75	137	10
128	20,000	T	OS	82	120	20	82	133	10	75	132	10
129	30,000	T	A-305	65	214	15	65	135	10	55	159	10
130	30,000	T	A-305	81	213	15	81	202	10	66	164	10
131	30,000	T	OS	75	144	15	75	114	15	75	142	15
132	30,000	T	OS	72	147	25	72	115	20	61	145	15
133	30,000	T	A-305	77	119	20	77	118	15	63	121	10
134	30,000	T	A-305	78	122	25	78	133	15	66	121	10
135	30,000	T	OS	73	134	30	73	96	20	66	121	10
136	30,000	T	OS	77	148	25	77	112	20	66	149	15
137	40,000	T	A-305	64	173	25	64	164	20	51	167	20
138	40,000	T	A-305	68	171	40	68	183	30	57	194	25
139	40,000	T	OS	75	139	35	75	145	20	69	129	15
140	40,000	T	OS	70	136	30	70	149	15	69	145	15
141	40,000	T	A-305	68	231	25	68	218	25	55	267	20
142	40,000	T	A-305	73	228	20	73	193	15	60	220	15
143	40,000	T	OS	66	223	20	66	169	15	65	225	15
144	40,000	T	OS	75	226	25	75	171	20	63	209	20
145	50,000	T	A-305	70	236	25	70	170	20	71	224	15
146	50,000	T	A-305	64	235	30	64	173	20	55	237	15
147	50,000	T	OS	61	232	105	61	221	100	59	271	90
148	50,000	T	OS	64	242	110	64	258	90	64	268	85
149	50,000	T	A-305	70	228	30	70	164	15	70	224	20
150	50,000	T	A-305	66	240	35	66	165	25	67	224	15
151	50,000	T	OS	68	155	30	68	170	25	60	156	25
152	50,000	T	OS	61	173	35	61	197	30	55	179	25
153	None	T	A-305	55	116	0	55	123	0	51	128	0
154	None	T	A-305	80	114	0	80	123	0	77	115	0
155	None	T	A-305	77	116	0	77	106	0	72	136	0
156	None	T	OS	88	111	0	88	117	0	82	125	0
157	None	T	OS	70	115	0	70	123	0	67	131	0
158	None	T	OS	54	117	20	54	125	15	53	123	10

Beach Row 1

				1962-1964 Readings								
				976 Cycles, 1962			1082 Cycles, 1963			1217 Cycles, 1964		
				Condition	$\delta V^2$	Max Crack Width 1/1000 in.	Condition	$\delta V^2$	Max Crack Width 1/1000 in.	Condition	$\delta V^2$	Max Crack Width 1/1000 in.
83	20,000	B	A-305	68	192	10	80	131	20	68	118	15
84	20,000	B	A-305	75	174	10	82	126	20	70	116	15
85	20,000	B	OS	77	162	15	87	101	30	74	107	20
86	20,000	B	OS	73	159	10	80	112	25	67	103	20
87	20,000	B	A-305	58	174	10	72	127	20	58	127	10
88	20,000	B	A-305	61	184	10	61	137	10	52	130	10
89	20,000	B	OS	71	173	10	86	114	20	72	121	15
90	20,000	B	OS	67	171	10	66	100	20	66	115	15
91	30,000	B	A-305	71	143	15	70	112	30	70	100	25
92	30,000	B	A-305	67	150	15	66	108	35	72	106	20

(Continued)

(Sheet 3)

(Revised Aug 1965)

Table 1-TC-B (Continued)

Section 2

Beach Row 1

Beam No.	Nominal Stress psi	Steel Position	Type Steel Deformation	1962-1964 Readings								
				976 Cycles, 1962			1082 Cycles, 1963			1217 Cycles, 1964		
				Condition	Max Crack Width $\sqrt{V}$ 1/1000 in.	Condition	Max Crack Width $\sqrt{V}$ 1/1000 in.	Condition	Max Crack Width $\sqrt{V}$ 1/1000 in.	Condition	Max Crack Width $\sqrt{V}$ 1/1000 in.	Condition
93	30,000	B	OS	71	136	20	70	106	40	70	91	30
94	30,000	B	OS	69	163	25	69	133	40	69	109	30
95	30,000	B	A-305	79	148	15	94	105	30	76	100	20
96	30,000	B	A-305	69	162	20	81	120	35	69	107	25
97	30,000	B	OS	64	147	10	64	109	30	65	60	25
98	30,000	B	OS	64	154	15	63	111	25	63	105	25
99	40,000	B	A-305	62	180	15	62	136	30	62	83	20
100	40,000	B	A-305	64	212	15	75	143	25	64	132	15
101	40,000	B	OS	64	184	25	62	136	30	65	122	25
102	40,000	B	OS	67	206	20	66	143	35	67	127	30
103	40,000	B	A-305	59	210	15	72	143	40	61	174	30
104	40,000	B	A-305	66	258	25	77	154	50	65	197	35
105	40,000	B	OS	72	258	20	72	145	30	72	169	20
106	40,000	B	OS	56	244	15	66	139	30	56	165	30
107	50,000	B	A-305	54	194	15	53	131	30	53	138	25
108	50,000	B	A-305	59	134	15	57	107	30	58	110	30
109	50,000	B	OS	68	192	25	68	183	50	67	175	50
110	50,000	B	OS	55	197	25	55	148	45	56	140	50
111	50,000	F	A-305	58	256	25	57	163	50	58	177	30
112	50,000	B	A-305	66	267	15	65	159	30	65	177	25
113	50,000	B	OS	49	204	15	49	170	30	50	177	25
114	50,000	B	OS	54	285	20	54	183	35	54	194	35
115	None	B	A-305	66	113	0	78	93	0	64	93	0
116	None	B	A-305	70	112	5	80	76	15	80	89	10
117	None	B	A-305	73	120	10	67	76	30	68	93	30
118	None	B	OS	44	96	0	55	76	0	44	84	0
119	None	B	OS	58	124	0	70	74	0	58	97	0
120	None	B	OS	58	114	0	70	80	0	57	98	0
121	20,000	T	A-305	74	236	10	87	156	10	80	159	10
122	20,000	T	A-305	69	227	10	82	140	10	75	151	20
123	20,000	T	OS	61	238	10	72	139	20	72	154	25
124	20,000	T	OS	65	229	10	77	148	25	65	148	20
125	20,000	T	A-305	64	134	10	70	82	10	64	82	5
126	20,000	T	A-305	77	115	10	90	77	20	77	88	10
127	20,000	T	OS	80	130	10	82	87	20	82	77	20
128	20,000	T	OS	70	138	10	69	90	20	70	87	20
129	30,000	T	A-305	55	225	10	65	137	20	55	154	15
130	30,000	T	A-305	66	228	15	55	119	30	66	155	25
131	30,000	T	OS	74	133	15	74	83	40	74	108	40
132	30,000	T	OS	61	143	10	61	84	20	61	108	35
133	30,000	T	A-305	63	125	10	74	85	20	63	88	20
134	30,000	T	A-305	66	128	10	66	87	20	66	86	20
135	30,000	T	OS	62	131	15	73	77	30	67	89	15
136	30,000	T	OS	66	159	15	77	104	20	66	114	20
137	40,000	T	A-305	51	154	20	51	130	40	51	112	35
138	40,000	T	A-305	57	187	20	57	132	40	57	108	40
139	40,000	T	OS	67	139	15	69	98	30	68	97	20
140	40,000	T	OS	69	140	10	69	100	30	69	87	25
141	40,000	T	A-305	55	247	15	55	155	35	55	165	35
142	40,000	T	A-305	63	218	15	59	150	30	60	174	30
143	40,000	T	OS	65	236	15	65	152	35	66	167	35
144	40,000	T	OS	64	226	15	75	152	40	63	148	35
145	50,000	T	A-305	71	257	25	70	176	40	70	160	40
146	50,000	T	A-305	55	175	20	64	165	40	54	168	40
147	50,000	T	OS	60	266	100	59	177	180	60	173	160
148	50,000	T	OS	64	278	90	63	175	140	64	175	125
149	50,000	T	A-305	70	170	20	70	167	40	70	164	40
150	50,000	T	A-305	67	248	20	66	171	40	67	164	50
151	50,000	T	OS	60	176	25	59	120	50	60	119	50
152	50,000	T	OS	54	195	25	54	125	55	54	128	50

(Continued)

(Sheet 4)

(Revised Sept 1968)  
Table 1-TC-B (Continued)

Section 2

1962-1964 Readings													Beach Row 1	
Beam No.	Nominal Stress psi	Steel Position	Type Steel Deformation	976 Cycles, 1962			1082 Cycles, 1963			1217 Cycles, 1964			Beach Row 1	
				Condi- tion	Max Crack Width		Condi- tion	Max Crack Width		Condi- tion	Max Crack Width			
					$\Delta V^2$	1/1000 in.		$\Delta V^2$	1/1000 in.		$\Delta V^2$	1/1000 in.		
153	None	T	A-305	47	121	0	55	97	0	51	94	0		
154	None	T	A-305	74	118	0	80	92	0	80	97	0		
155	None	T	A-305	71	121	0	77	91	0	77	90	0		
156	None	T	OS	81	123	0	88	89	0	75	97	0		
157	None	T	OS	60	118	0	70	88	0	64	91	0		
158	None	T	OS	53	123	15	63	88	25	53	90	15		
1965-1967 Readings														
1666 Cycles, 1967														
				1380 Cycles, 1965		1510 Cycles, 1966						Max Crack Width 1/1000 in.		
				Con- di- tion	Max Crack Width 1/1000 in.	Con- di- tion	Max Crack Width 1/1000 in.	Con- di- tion	Before Unload- ing	Not Loaded	After Re-load- ing	Before Unload- ing	Not Loaded	After Re-load- ing
83	20,000	B	A-305	*	93	5	65	**	10	*	116	99	10	10
84	20,000	B	A-305		90	10	70		15		93	116	15	15
85	20,000	B	OS		65	10	72		10		85	58	10	10
86	20,000	B	OS		83	15	66		15		83	56	15	20
87	20,000	B	A-305		104	10	52		15		125	95	15	15
88	20,000	B	A-305		120	5	50		5		97	64	5	10
89	20,000	B	OS		109	5	69		5		92	66	5	15
90	20,000	B	OS		102	10	66		10		108	88	10	10
91	30,000	B	A-305		65	15	70		15		83	54	15	20
92	30,000	B	A-305		67	15	78		15		83	60	15	25
93	30,000	B	OS		69	20	68		25		95	81	25	40
94	30,000	B	OS		62	25	64		35		86	110	35	50
95	30,000	B	A-305		74	15	72		20		100	85	25	30
96	30,000	B	A-305		104	15	68		25		111	57	25	25
97	30,000	B	OS		71	20	62		20		84	61	20	30
98	30,000	B	OS		70	20	63		25		85	64	20	35
99	40,000	B	A-305		94	20	62		30		106	75	25	30
100	40,000	B	A-305		94	15	64		30		106	83	30	30
101	40,000	B	OS		84	35	62		50		86	74	50	55
102	40,000	B	OS		79	30	65		50		98	80	45	50
103	40,000	B	A-305		138	30	52		35		117	93	35	40
104	40,000	B	A-305		148	25	65		30		137	114	30	45
105	40,000	B	OS		120	20	71		30		139	96	30	35
106	40,000	B	OS		118	20	56		30		154	123	25	35
107	50,000	B	A-305		110	25	52		30		129	90	25	35
108	50,000	B	A-305		77	25	58		25		105	57	25	30
109	50,000	B	OS		97	40	66		45		166	105	45	55
110	50,000	B	OS		96	40	55		40		128	111	45	50
111	50,000	B	A-305		104	30	54		30		170	90	25	40
112	50,000	B	A-305		143	25	63		30		127	86	25	35
113	50,000	B	OS		147	20	49		30		119	97	35	45
114	50,000	B	OS		177	25	53		40		172	144	40	55
115	None	B	A-305		76	0	60		0					0
116	None	B	A-305		83	10	65		10					10
117	None	B	A-305		60	20	68		10					10
118	None	B	OS		84	0	41		0					0
119	None	B	OS		59	0	52		0					0
120	None	B	OS		64	0	54		0					0
121	20,000	T	A-305		113	10	87		15		147	113	15	15
122	20,000	T	A-305		136	10	82		10		129	143	10	15
123	20,000	T	OS		136	15	72		15		141	83	15	30
124	20,000	T	OS		143	10	71		15		144	97	15	25
125	20,000	T	A-305		79	5	64		5		84	53	5	10
126	20,000	T	A-305		82	5	77		10		82	62	10	10
127	20,000	T	OS		64	5	82		5		65	64	5	10
128	20,000	T	OS		66	5	70		10		69	87	5	5
129	30,000	T	A-305		136	15	65		20		117	77	15	15
130	30,000	T	A-305		106	20	77		20		132	79	25	25
131	30,000	T	OS		71	30	74		45		60	48	45	50
132	30,000	T	OS		83	30	61		30		86	56	30	40

(Continued)

\* In 1965 and 1967 the condition of specimens was not rated by panel of observers.

(Sheet 5)

† Satisfactory pulse velocity readings were not obtained in 1966 due to malfunction of testing equipment.

‡ Channel iron on all loaded beams was replaced with stainless steel channel in June 1967. Readings were therefore taken on all loaded beams before unloading and after reloading with stainless steel channel.

(Revised Jan 1973)

Table 1-TC-B (Continued)

Section 2

Beach Row 1

1965-1967 Readings												
1666 Cycles, 1967												
Beam No.	Nominal Stress psi	Steel Position	Type Steel Deformation	1380 Cycles, 1965		1510 Cycles, 1966		Condi- tion	Before Unload- ing	$\%V^2$		After Re-load- ing
				Con- di- tion	Max Crack Width 1/1000 in.	Con- di- tion	Max Crack Width 1/1000 in.			Not Loaded	Max Crack Width 1/1000 in.	
133	30,000	T	A-305	*	59	15	63	15	82			15
134	30,000	T	A-305		83	15	72	20	84			15
135	30,000	T	OS		75	15	67	25	65			30
136	30,000	T	OS		89	25	65	30	79			35
137	40,000	T	A-305		73	40	51	55	91			70
138	40,000	T	A-305		83	40	57	50	98			75
139	40,000	T	OS		57	20	67	30	70			35
140	40,000	T	OS		70	20	69	35	74			35
141	40,000	T	A-305		106	30	55	30	155			45
142	40,000	T	A-305		116	30	59	35	135			40
143	40,000	T	OS		143	25	65	25	119			30
144	40,000	T	OS		118	35	62	45	109			60
145	50,000	T	A-305		139	30	70	45	103			70
146	50,000	T	A-305		120	30	53	35	114			45
147	50,000	T	OS		98	100	59	125	162			125
148	50,000	T	OS		116	85	64	100	157			120
149	50,000	T	A-305		147	35	69	50	124			50
150	50,000	T	A-305		150	40	65	40	145			50
151	50,000	T	OS		71	35	57	35	111			45
152	50,000	T	OS		82	35	54	45	102			45
153	None	T	A-305		96	0	44	0		74		0
154	None	T	A-305		75	0	67	0		73		0
155	None	T	A-305		67	0	77	0		70		0
156	None	T	OS		74	0	66	0		69		0
157	None	T	OS		64	0	60	0		87		0
158	None	T	OS		53	15	52	10		68		10

Beach Row 1

1968-1972 Readings																			
1851 Cycles, 1968				2005 Cycles, 1969				2158 Cycles, 1970				2327 Cycles, 1971				2484 Cycles, 1972			
				Con-	Max	Con-	Max	Con-	Max	Con-	Max	Con-	Max	Con-	Max				
				di-	Crack	di-	Crack	di-	Crack	di-	Crack	di-	Crack	di-	Crack				
				tion	Width	tion	Width	tion	Width	tion	Width	tion	Width	tion	Width				
					1/1000		1/1000		1/1000		1/1000		1/1000		1/1000				
					$\delta V^2$		$\delta V^2$		$\delta V^2$		$\delta V^2$		$\delta V^2$		$\delta V^2$				
					in.		in.		in.		in.		in.		in.				
83	20,000	B	A-305	65	116	15	62	40	15	59	69	15	60	62	15				
84	20,000	B	A-305	68	95	15	68	37	20	67	71	20	66	51	15				
85	20,000	B	OS	72	61	20	72	28	20	71	53	25	70	51	25				
86	20,000	B	OS	66	84	15	66	35	20	64	57	20	64	55	25				
87	20,000	B	A-305	52	93	20	53	41	25	52	63	25	47	58	30				
88	20,000	B	A-305	50	84	20	54	44	25	59	70	25	51	68	20				
89	20,000	B	OS	69	75	20	67	42	20	68	73	20	68	67	25				
90	20,000	B	OS	63	104	10	64	37	15	65	61	25	62	58	30				
91	30,000	B	A-305	70	85	20	70	35	20	70	56	25	69	53	25				
92	30,000	B	A-305	76	66	20	67	35	20	67	55	20	66	51	25				
93	30,000	B	OS	68	53	40	66	32	40	64	51	40	64	49	40				
94	30,000	B	OS	64	78	50	66	35	50	67	60	55	68	55	55				
95	30,000	B	A-305	72	100	35	72	34	35	68	53	40	68	50	35				
96	30,000	B	A-305	68	109	30	67	41	35	66	68	35	65	59	30				
97	30,000	B	OS	62	76	30	64	34	35	61	61	35	61	56	35				
98	30,000	B	OS	63	87	30	62	34	30	62	58	35	61	54	40				
99	40,000	B	A-305	62	110	35	60	70	35	59	58	35	59	53	40				
100	40,000	B	A-305	64	75	30	63	37	30	60	60	35	57	52	35				
101	40,000	B	OS	62	86	60	61	39	70	61	59	70	61	52	75				
102	40,000	B	OS	65	98	50	64	33	50	64	50	55	62	49	60				
103	40,000	B	A-305	51	79	45	53	50	50	53	75	50	51	71	55				
104	40,000	B	A-305	65	99	45	62	52	50	62	79	50	59	76	50				
105	40,000	B	OS	71	111	45	71	56	45	68	87	45	67	84	50				
106	40,000	B	OS	54	81	50	54	46	55	54	73	55	54	67	50				
107	50,000	B	A-305	52	92	40	52	33	45	52	54	45	52	52	50				

\* In 1965 and 1967 the condition of specimens was not rated by panel of observers.

(Sheet 6)

\*\* Satisfactory pulse velocity readings were not obtained in 1966 due to malfunction of testing equipment.

# Channel iron on all loaded beams was replaced with stainless steel channel in June 1967. Readings were therefore taken on all loaded beams before unloading and after reloading with stainless steel channel.

# Some pulse velocity readings obtained in 1969 and 1970 are not believed to be valid due to the power limitations of the test equipment; these  $\%V^2$  readings are therefore questionable.

(Revised Jan 1973)

Table 1-TC-B (Concluded)

Section 2

Beach Row 1

Beam No.	Nominal Stress psi	Steel Position	Type Steel Deformation	1968-1972 Readings														
				1851 Cycles, 1968			2005 Cycles, 1969			2158 Cycles, 1970			2327 Cycles, 1971			2484 Cycles, 1972		
				Con- di- tion	Max Crack Width 1/1000 in.	$\%V^2$	Con- di- tion	Max Crack Width 1/1000 in.	$\%V^2$	Con- di- tion	Max Crack Width 1/1000 in.	$\%V^2$	Con- di- tion	Max Crack Width 1/1000 in.	$\%V^2$	Con- di- tion	Max Crack Width 1/1000 in.	$\%V^2$
108	50,000	B	A-305	57	73	40	57	26	45	57	41	45	55	40	45	56	37	50
109	50,000	B	OS	66	149	50	66	59	50	66	99	55	66	91	55	66	64	50
110	50,000	B	OS	55	117	50	55	56	50	55	95	55	55	81	50	56	47	50
111	50,000	B	A-305	53	91	50	55	52	50	56	79	50	51	72	50	53	62	40
112	50,000	B	A-305	63	93	40	63	50	45	63	76	45	62	71	40	63	65	40
113	50,000	B	OS	49	103	55	49	53	55	48	92	60	48	86	60	48	59	60
114	50,000	B	OS	53	180	55	52	42	65	52	64	65	50	62	70	50	64	70
115	None	B	A-305	59	68	0	59	26	0	58	43	0	56	39	0	58	32	0
116	None	B	A-305	65	58	5	67	25	0	67	38	0	66	36	0	65	29	0
117	None	B	A-305	65	68	0	65	28	0	65	43	0	67	40	0	65	30	0
118	None	B	OS	40	66	0	39	27	0	43	43	0	44	41	0	36	44	0
119	None	B	OS	52	67	0	53	30	0	56	49	0	52	47	0	51	21	0
120	None	B	OS	54	69	0	56	27	0	56	43	0	55	41	0	54	27	0
121	20,000	T	A-305	87	91	25	74	49	25	74	79	25	71	73	25	74	86	30
122	20,000	T	A-305	82	85	25	70	52	30	69	81	25	67	77	20	68	54	25
123	20,000	T	OS	72	119	30	61	47	35	61	76	40	61	74	35	60	51	40
124	20,000	T	OS	71	111	35	65	59	40	65	98	40	65	92	45	65	51	50
125	20,000	T	A-305	64	45	20	60	34	20	59	59	25	58	33	25	60	33	30
126	20,000	T	A-305	77	63	20	77	34	25	76	60	25	77	49	30	76	42	30
127	20,000	T	OS	76	68	10	69	28	10	70	42	10	68	37	20	68	22	15
128	20,000	T	OS	69	69	5	69	27	5	70	47	10	68	43	15	67	25	15
129	30,000	T	A-305	60	90	20	55	50	25	55	77	30	53	73	35	55	56	40
130	30,000	T	A-305	71	84	35	66	45	35	65	69	35	62	66	35	63	54	35
131	30,000	T	OS	74	56	50	73	34	50	74	52	50	72	47	55	72	53	50
132	30,000	T	OS	61	84	40	61	35	50	61	54	50	58	51	50	58	42	40
133	30,000	T	A-305	63	45	20	63	26	25	63	44	30	61	43	30	61	40	30
134	30,000	T	A-305	66	61	25	66	28	25	66	47	25	64	45	25	65	45	30
135	30,000	T	OS	62	53	35	61	28	30	61	44	30	61	42	35	60	32	40
136	30,000	T	OS	65	63	35	63	33	30	64	50	25	61	48	25	62	56	25
137	40,000	T	A-305	51	89	70	49	##	70	49	50	70	49	50	75	49	47	70
138	40,000	T	A-305	57	106	70	56	37	70	56	60	75	56	56	70	56	45	60
139	40,000	T	OS	67	92	35	67	26	40	66	39	45	66	38	45	66	32	40
140	40,000	T	OS	69	82	35	70	29	40	68	53	40	67	49	40	68	32	40
141	40,000	T	A-305	55	99	55	54	52	55	54	91	60	53	84	60	53	67	60
142	40,000	T	A-305	59	111	50	58	50	55	57	80	60	57	84	65	62	59	60
143	40,000	T	OS	65	116	30	64	48	35	64	74	35	64	71	30	64	61	25
144	40,000	T	OS	61	115	55	61	51	60	61	80	65	61	73	70	61	61	60
145	50,000	T	A-305	68	101	65	66	50	70	65	84	65	56	79	65	54	63	60
146	50,000	T	A-305	52	98	50	51	68	55	49	116	55	48	96	55	47	55	60
147	50,000	T	OS	Failed §§														
148	50,000	T	OS	Damaged														
149	50,000	T	A-305	68	126	45	68	50	55	68	83	60	67	77	55	68	60	50
150	50,000	T	A-305	65	142	50	65	62	50	64	86	50	65	80	50	65	54	50
151	50,000	T	OS	57	79	50	58	30	50	57	49	55	57	45	55	57	39	50
152	50,000	T	OS	54	111	50	54	40	55	54	66	55	54	63	50	54	31	50
153	None	T	A-305	44	72	0	44	30	0	46	48	0	43	45	0	44	33	0
154	None	T	A-305	61	64	0	62	29	0	62	45	0	55	44	0	57	34	0
155	None	T	A-305	66	63	0	65	30	0	66	44	0	66	40	0	65	32	0
156	None	T	OS	66	74	0	68	29	0	63	46	0	66	31	0	66	35	0
157	None	T	OS	60	79	0	60	29	0	60	46	0	56	44	0	52	32	0
158	None	T	OS	52	67	10	53	33	10	53	52	10	52	45	15	53	66	10

§§ Beam failed but left under exposure.

|| Damaged when beam 147 failed, but left under exposure.

# Some pulse velocity readings obtained in 1969 and 1970 are not believed to be valid due to the power limitations of the test equipment; these  $\%V^2$  readings are therefore questionable.

## A pulse velocity reading was not obtained on this specimen.

(Sheet 7)

(Revised August 1977)

Table 1-TC-B (Continued)

Section 2

Beam No.	Nominal Stress psi	Steel Position	Type Steel Deformation	Condi- tion	1973-1976 Readings							
					2624 Cycles, 1973		2760 Cycles, 1974		2872 Cycles, 1975		3018 Cycles, 1976	
					Max Crack Width 1/1000 in.	Con- di- tion	Max Crack Width 1/1000 in.	Con- di- tion	Max Crack Width 1/1000 in.	Con- di- tion	Max Crack Width 1/1000 in.	Con- di- tion
83	20,000	B	A-305	59	10	53	5	59	74	10	46	66
84	20,000	B	A-305	63	10	67	10	65	67	15	64	74
85	20,000	B	OS	72	25	71	20	71	72	25	66	73
86	20,000	B	OS	66	20	66	20	66	66	20	63	65
87	20,000	B	A-305	46	15	48	15	45	70	20	47	105
88	20,000	B	A-305	50	10	49	15	49	68	20	51	69
89	20,000	B	OS	64	20	66	20	65	76	25	64	76
90	20,000	B	OS	61	20	60	20	60	60	30	57	97
91	30,000	B	A-305	69	20	68	20	67	56	30	68	55
92	30,000	B	A-305	67	15	66	15	66	83	20	51	80
93	30,000	B	OS	64	25	66	40	64	53	35	64	53
94	30,000	B	OS	67	55	67	70	64	57	70	61	65
95	30,000	B	A-305	68	20	68	15	67	78	25	62	77
96	30,000	B	A-305	65	20	66	20	67	53	25	62	80
97	30,000	B	OS	63	40	63	30	61	59	50	62	58
98	30,000	B	OS	59	50	58	50	60	63	50	58	62
99	40,000	B	A-305	59	50	59	60	59	57	50	57	58
100	40,000	B	A-305	58	40	56	30	57	73	50	53	71
101	40,000	B	OS	58	60	60	70	60	53	75	58	52
102	40,000	B	OS	61	60	63	60	63	46	70	59	49
103	40,000	B	A-305	50	60	51	60	48	89	60	47	94
104	40,000	B	A-305	57	60	58	50	58	76	55	57	81
105	40,000	B	OS	69	50	70	50	68	110	55	64	108
106	40,000	B	OS	52	50	52	50	52	63	70	48	66
107	50,000	B	A-305	51	50	51	60	51	38	55	51	38
108	50,000	B	A-305	55	50	52	50	54	37	55	57	38
109	50,000	B	OS	66	60	66	70	66	62	60	64	126
110	50,000	B	OS	55	60	55	60	53	57	60	55	100
111	50,000	B	A-305	51	40	50	50	51	83	50	49	92
112	50,000	B	A-305	63	60	62	70	58	74	60	61	103
113	50,000	B	OS	48	80	48	80	48	75	80	47	76
114	50,000	B	OS	51	70	52	60	52	71	75	51	138
115	None	B	A-305	63	0	57	0	56	79		47	79
116	None	B	A-305	65	0	58	0	57	82		55	79
117	None	B	A-305	43	0	45	0	48	42		35	42
118	None	B	OS	34	0	35	0	38	61		35	65
119	None	B	OS	56	0	49	0	49	40		50	43
120	None	B	OS	53	0	54	0	48	83		52	80
121	20,000	T	A-305	74	30	72	25	72	97	35	72	98
122	20,000	T	A-305	69	20	68	15	67	90	25	69	102
123	20,000	T	OS	60	50	61	50	60	90	50	60	103
124	20,000	T	OS	64	40	64	40	62	86	50	61	81
125	20,000	T	A-305	60	25	59	20	56	55	30	57	56
126	20,000	T	A-305	76	25	77	25	74	57	30	75	58
127	20,000	T	OS	65	15	67	20	66	57	20	67	56
128	20,000	T	OS	58	10	67	10	64	61	20	68	59
129	30,000	T	A-305	54	50	52	40	54	75	50	52	98
130	30,000	T	A-305	63	50	63	50	63	70	60	61	111
131	30,000	T	OS	72	60	72	60	70	62	70	72	62
132	30,000	T	OS	59	60	59	60	58	71	60	51	83
133	30,000	T	A-305	60	50	61	50	58	83	50	57	78
134	30,000	T	A-305	64	60	64	50	64	60	65	62	61
135	30,000	T	OS	61	40	61	40	61	50	40	61	46
136	30,000	T	OS	65	20	65	30	62	82	30	63	86
137	40,000	T	A-305	49	80	50	70	49	66	85	49	67
138	40,000	T	A-305	56	75	55	80	56	68	75	55	67
139	40,000	T	OS	66	50	65	60	65	92	50	64	68
140	40,000	T	OS	67	45	67	40	67	65	55	66	67
141	40,000	T	A-305	53	60	53	60	52	75	60	58	105
142	40,000	T	A-305	53	40	59	50	54	70	50	61	86
143	40,000	T	OS	64	40	63	40	62	78	50	64	114
144	40,000	T	OS	61	60	61	70	55	72	65	59	91
145	50,000	T	A-305	60	80	54	80	52	68	80	54	116
146	50,000	T	A-305	46	50	48	60	44	72	70	46	84

\*\* Satisfactory pulse velocity readings were not obtained in 1973 and 1974.

(Sheet 8)

(Issued August 1977)

Table 1-TC-B (Continued)

Section 2

Beach Row 1

Beam No.	Nominal Stress psi	Steel Posi- tion	Type Steel Deform- ation	Con- di- tion	3095 Cycles, 1977	
					$\delta v^2$	Max Crack Width 1/1000 in.
83	20,000	B	A-305	22	80	15
84	20,000	B	A-305	60	74	25
85	20,000	B	OS	68	88	25
86	20,000	B	OS	65	69	25
87	20,000	B	A-305	46	66	20
88	20,000	B	A-305	51	53	20
89	20,000	B	OS	63	46	25
90	20,000	B	OS	58	59	25
91	30,000	B	A-305	68	60	25
92	30,000	B	A-305	65	84	25
93	30,000	B	OS	63	51	55
94	30,000	B	OS	63	68	70
95	30,000	B	A-305	60	76	25
96	30,000	B	A-305	64	86	25
97	30,000	B	OS	62	76	50
98	30,000	B	OS	59	63	50
99	40,000	B	A-305	56	92	60
100	40,000	B	A-305	56	72	55
101	40,000	B	OS	56	54	80
102	40,000	B	OS	58	53	100
103	40,000	B	A-305	47	86	60
104	40,000	B	A-305	64	62	60
105	40,000	B	OS	65	82	75
106	40,000	B	OS	66	69	70
107	50,000	B	A-305	50	46	(1-in. spall)
108	50,000	B	A-305	53	44	(5/8-in. spall)
109	50,000	B	OS	65	115	(1-1/2 in. spall)
110	50,000	B	OS	53	94	75
111	50,000	B	A-305	50	68	75
112	50,000	B	A-305	59	67	75
113	50,000	B	OS	47	79	(1/4-in. spall)
114	50,000	B	OS	51	101	100
115	None	B	A-305	51	78	
116	None	B	A-305	57	76	
117	None	B	A-305	59	44	
118	None	B	OS	44	64	
119	None	B	OS	55	43	
120	None	B	OS	54	79	
121	20,000	T	A-305	70	92	35
122	20,000	T	A-305	67	97	35
123	20,000	T	OS	59	65	60
124	20,000	T	OS	63	71	60
125	20,000	T	A-305	57	54	30
126	20,000	T	A-305	75	54	30
127	20,000	T	OS	66	68	20
128	20,000	T	OS	67	65	20
129	30,000	T	A-305	52	93	50
130	30,000	T	A-305	60	83	60
131	30,000	T	OS	70	49	75
132	30,000	T	OS	54	53	75
133	30,000	T	A-305	58	91	50
134	30,000	T	A-305	62	72	75
135	30,000	T	OS	61	43	40
136	30,000	T	OS	62	59	40
137	40,000	T	A-305	49	79	100
138	40,000	T	A-305	55	77	75
139	40,000	T	OS	65	89	55
140	40,000	T	OS	65	81	60
141	40,000	T	A-305	59	94	60
142	40,000	T	A-305	57	86	60
143	40,000	T	OS	62	81	75
144	40,000	T	OS	57	93	(3/8-in. spall)
145	50,000	T	A-305	52	89	125
146	50,000	T	A-305	47	73	80

(Issued August 1977)

Table 1-TC-B (Continued)

Section 2

1973-1976 Readings													Beach Row 1
		2624 Cycles, 1973		2760 Cycles, 1974		2872 Cycles, 1975		3018 Cycles, 1976					
Beam No.	Nominal Stress psi	Steel Position	Steel Deformation	Con-dition	$\%V^2$	Max Crack Width 1/1000 in.	Con-dition	$\%V^2$	Max Crack Width 1/1000 in.	Con-dition	$\%V^2$	Max Crack Width 1/1000 in.	
148	50,000	T	OS		##		Unloaded	##					
149	50,000	T	A-305	68		75	66		500%	61	73	500	61 100 (4-in. spall)
150	50,000	T	A-305	65		60	65		70	62	61	70	64 104 75
151	50,000	T	OS	57		70	58		70	57	62	60	56 63 (1/2-in. spall)
152	50,000	T	OS	54		60	54		55	51	52	50	53 52 50
153	None	T	A-305	44		0	36		0	16	50	26	52
154	None	T	A-305	55		0	54		0	54	84	55	81
155	None	T	A-305	76		0	65		0	61	82	65	81
156	None	T	OS	52		0	27		0	25	83	22	81
157	None	T	OS	52		0	51		0	49	83	50	90
158	None	T	OS	51		0	50		0	50	74	51	79 (2-in. spall)

3095 Cycles, 1977						1977- Readings
						Max Crack Width 1/1000 in.
Con- di- tion				$\%V^2$		
148	50,000	T	OS	--	--	--
149	50,000	T	A-305	64	67	(4-in. spall)
150	50,000	T	A-305	63	65	75
151	50,000	T	OS	53	63	(5/8-in. spall)
152	50,000	T	OS	53	67	50
153	None	T	A-305	29	53	
154	None	T	A-305	55	74	
155	None	T	A-305	65	82	
156	None	T	OS	23	82	
157	None	T	OS	54	80	
158	None	T	OS	50	68	

## Satisfactory pulse velocity readings were not obtained in 1973 and 1974.  
† One rebar failed during winter of 1973-1974.

(Corrected Aug 1965)

Section 3

Stewart Field Spheres\*

Twenty-four air-entrained concrete spheres were installed on the beach at Treat Island in May 1954 for soniscope studies. These spheres are 12 in. in diameter and were fabricated in March and April of 1943. They had previously been exposed at Treat Island during the period from October 1943 to May 1949 as a part of the Stewart Field Program. This previous exposure (approximately 600 cycles of freezing-and-thawing) had no appreciable effect on the spheres. Spheres were selected for this exposure primarily because the concrete in a sphere is in a relatively stress-free condition with no corners.

Table 1-SF lists these specimens and gives their exposure record along with pertinent mixture data.

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\* See Corps of Engineers, Central Concrete Laboratory, Concrete Investigation, Stewart Field, Newburgh, New York, First Interim Report (March 1943); Second Interim Report (April 1943); Final Report (April 1944).

(Revised Aug 1974)

Table 1-SF

Section 3

## Mixture Data and Record of Testing of Stewart Field Spheres

1954- (Installed May 1954)

Sphere No.	Aggregate Combination		Water-Cement Ratio gal/bag	Cement Factor bags/cu yd	Air %	Exposure Rack, Row 9 (W to E)										
						1954-1962 Readings										
						1954	1955	1956	1957	1958	1959	1960	1961	1962		
	Fine	Coarse				Pulse Veloc fps	$\frac{V}{V^2}$	$\frac{V}{V^2}$	$\frac{V}{V^2}$	$\frac{V}{V^2}$	$\frac{V}{V^2}$	$\frac{V}{V^2}$	$\frac{V}{V^2}$	$\frac{V}{V^2}$		
11A	Nat. sand A	Nat. gravel A	4.5	7.2	3.2	14,925	100	94	106	103	113	*				
11B	Nat. sand A	Nat. gravel A	4.5	7.1	4.0	14,085	100	109	131	97	123	105	102	123	119	
11G	Nat. sand A	Nat. gravel A	4.5	7.0	2.9	13,890	100	112	127	116	131	103	109	119	115	
12D	Nat. sand A	Nat. gravel A	5.0	6.2	2.3	14,925	100	97	117	94	94	87	92	117	94	
13D	Nat. sand A	Nat. gravel A	5.5	5.3	4.7	16,665	100	100	111	94	100	85	91	103	73	
21A	Crushed	Nat. gravel A	4.5	7.3	4.5	14,495	100	106	109	106	116	106	113	137	113	
21B	Crushed	Nat. gravel A	4.5	7.3	4.3	14,925	100	100	128	109	124	113	124	125	117	
22A	Crushed	Nat. gravel A	5.0	6.4	4.8	13,700	100	106	119	116	123	113	120	130	139	
22B	Crushed	Nat. gravel A	5.0	6.4	4.7	13,335	100	118	115	115	109	115	132	162	133	
23A	Crushed	Nat. gravel A	5.5	5.6	4.5	14,085	100	106	123	106	119	100	106	135	131	
23B	Crushed	Nat. gravel A	5.5	5.6	4.6	13,890	100	112	127	116	127	106	109	135	140	
31D	Nat. sand B	Nat. gravel A	4.5	6.5	4.3	14,925	100	106	121	110	125	110	110	121	113	
33D	Nat. sand B	Nat. gravel A	5.5	5.0	4.8	13,890	100	115	131	112	135	107	100	139	135	
52D	Blend A	Nat. gravel A	5.0	5.9	3.8	14,495	100	109	132	106	109	106	Failed			
53A	Blend B	Nat. gravel A	5.5	5.2	5.1	13,890	100	112	127	116	120	110	120	131	131	
53E	Blend A	Nat. gravel A	5.5	5.1	4.3	13,890	100	115	135	116	123	107	119	127	103	
71A	Crushed	Rock C	4.5	7.4	6.8	18,520	100	87	90	90	100	76	87	96	93	
73D	Crushed	Rock C	5.5	5.8	2.9	17,240	100	97	104	104	108	94	97	111	100	
81A	Nat. sand B	Rock C	4.5	7.0	4.9	16,665	100	97	123	110	114	96	106	124	85	
83A	Nat. sand B	Rock C	5.5	5.3	7.7	16,950	100	73	100	88	100	97	83	85	85	
83D	Nat. sand B	Rock C	5.5	5.3	4.1	16,395	100	103	128	111	100	85	94	107	66	
83E	Nat. sand B	Rock C	5.5	5.3	3.9	16,395	100	103	128	111	123	97	104	123	83	
92E	Blend C	Rock C	5.0	6.3	3.9	16,130	100	114	127	110	122	103	114	132	110	
13G	Nat. sand A	Nat. gravel A	5.5	5.2	3.8	15,385	100	89	106	94	**	114	94	106	94	

Sphere No.	Aggregate Combination		Water-Cement Ratio gal/bag	Cement Factor bags/cu yd	Air %	Exposure Rack, Row 9 (W to E)										
						1963-1972 Readings										
						1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	
						$\frac{V}{V^2}$	$\frac{V}{V^2}$	$\frac{V}{V^2}$	$\frac{V}{V^2}$	$\frac{V}{V^2}$	$\frac{V}{V^2}$	$\frac{V}{V^2}$	$\frac{V}{V^2}$	$\frac{V}{V^2}$	$\frac{V}{V^2}$	
11B	Nat. sand A	Nat. gravel A	4.5	7.1	4.0	90	112	119	†	87	119	123	103	83	58	
11G	Nat. sand A	Nat. gravel A	4.5	7.0	2.9	87	61	87		Failed						
12D	Nat. sand A	Nat. gravel A	5.0	6.2	2.3	106	103	121		82	92	89	87	33	43	
13D	Nat. sand A	Nat. gravel A	5.5	5.3	4.7	83	115	119		64	85	91	78	48	47	
21A	Crushed	Nat. gravel A	4.5	7.3	4.5	132	128	157		61	120	120	113	76	69	
21B	Crushed	Nat. gravel A	4.5	7.3	4.3	110	117	143		62	106	109	106	64	80	
22A	Crushed	Nat. gravel A	5.0	6.4	4.8	130	139	139		37	85	88	83	81	100	
22B	Crushed	Nat. gravel A	5.0	6.4	4.7	151	146	125		103	90	55	50	Failed		
23A	Crushed	Nat. gravel A	5.5	5.6	4.5	123	112	123		79	119	116	103	85	65	
23B	Crushed	Nat. gravel A	5.5	5.6	4.6	131	135	140		106	149	139	109	85	75	
31D	Nat. sand B	Nat. gravel A	4.5	6.5	4.3	117	117	106		41	40	Failed				
33D	Nat. sand B	Nat. gravel A	5.5	5.0	4.8	127	127	139		92	131	109	95	Failed		
53A	Blend B	Nat. gravel A	5.5	5.2	5.1	127	127	135		77	123	112	103	85	47	
53E	Blend A	Nat. gravel A	5.5	5.1	4.3	123	123	135		87	139	106	100	83	49	
71A	Crushed	Rock C	4.5	7.4	6.8	96	87	90		36	71	46	43	19	NR	
73D	Crushed	Rock C	5.5	5.8	2.9	111	50	69		Failed						
81A	Nat. sand B	Rock C	4.5	7.0	4.9	133	103	97		30	46	25	NR	Failed		
83A	Nat. sand B	Rock C	5.5	5.3	7.7	91	82	Failed								
83D	Nat. sand B	Rock C	5.5	5.3	4.1	97	63	33		Failed						
83E	Nat. sand B	Rock C	5.5	5.3	3.9	88	85	49		13	Failed					
92E	Blend C	Rock C	5.0	6.3	3.9	127	123	154		74	131	123	103	78	53	
13G	Nat. sand A	Nat. gravel A	5.5	5.2	3.8	110	110	114		58	114	86	77	61	51	

\* Specimen 11A disappeared between May 1958 and May 1959.

\*\* This specimen could not be found to test in 1958, but it was later found in another location on the beach and reinstalled.

† Satisfactory pulse velocity readings were not obtained in 1966 due to malfunction of testing equipment.

NR A satisfactory reading was not obtained although an attempt was made to obtain one.

(Sheet 1)

(Revised August 1977)

Table 1-SF (Continued)

Section 3

Exposure Rack, Row 9 (W to E)										
Sphere No.	Aggregate Combination		Water- Cement Ratio gal/bag	Cement Factor bags/cu yd	Air %	1973-1977 Readings				
	Fine	Coarse				1973	1974	1975	1976	1977
						\$V^2	\$V^2	\$V^2	\$V^2	\$V^2
11B	Nat. sand A	Nat. gravel A	4.5	7.1	4.0	52	49	33	NR	Failed
12D	Nat. sand A	Nat. gravel A	5.0	6.2	2.3	NR	NR	NR	NR	NR
13D	Nat. sand A	Nat. gravel A	5.5	5.3	4.7	NR	NR	NR	NR	NR
21A	Crushed	Nat. gravel A	4.5	7.3	4.5	66	60	80	73	73
21B	Crushed	Nat. gravel A	4.5	7.3	4.3	78	76	72	62	65
22A	Crushed	Nat. gravel A	5.0	6.4	4.8	95	93	88	81	83
23A	Crushed	Nat. gravel A	5.5	5.6	4.5	62	62	70	65	62
23B	Crushed	Nat. gravel A	5.5	5.6	4.6	43	40	67	61	63
53A	Blend B	Nat. gravel A	5.5	5.2	5.1	NR	NR	NR	Failed	
53E	Blend A	Nat. gravel A	5.5	5.1	4.3	NR	NR	NR	Failed	
71A	Crushed	Rock C	4.5	7.4	6.8	Failed				
92E	Blend C	Rock C	5.0	6.3	3.9	NR	NR	NR	Failed	
13G	Nat. sand A	Nat. gravel A	5.5	5.2	3.8	NR	NR	NR	Failed	

NR A satisfactory reading was not obtained although an attempt was made to obtain one.

(Sheet 2)

(Revised Sept 1968)

Section 4

Cement-Replacement Materials Investigation, Phase B\*

In December 1953, 21 concrete prisms (18 by 18 by 36 in.) were installed at half-tide elevation on the beach at Treat Island as a part of Phase B of the Cement-Replacement Materials Investigation.\* Phase B involved the proportioning, outdoor mixing, and placing of mass concrete, using 2-cu-yd batching, mixing, and placing equipment. The purpose of this installation is to develop information about the durability of Phase B concretes.

The prisms were made from seven different concrete mixtures (3 prisms per mixture); the coarse and fine aggregate used in all mixtures was a crushed limestone. All concrete mixtures were air-entrained; the air-entraining admixture was admixture G. The mixture data are tabulated below. Table 1-CRMI-PB lists the concrete specimens exposed as a part of this program and gives their exposure record.

Mix No.	Date Cast 1953	Mixture Data									
		Portland Cement		Replacement Material		Max Size Coarse Aggr	Cement Factor bags/cu yd	Water-Cement Ratio by wt	Slump in.	Air* %	Specimen No.
		Type	Used %	Type	Used %						
a	4-7	II	100	None	None	6 in.	2.52	0.8	2-1/4 2-3/4 3-1/4	6.0 6.7 5.1	B-10 B-11 B-12
b	4-14	II	100	None	None	3 in.	2.91	0.8	3/4 2-1/2 1-1/2	5.9 6.8 5.6	B-30 B-31 B-32
c	4-28	II	100	None	None	3 in.	4.76	0.5	2-1/2 1-1/2 1/4	7.2 2.5 1.2	B-61 B-62 B-63
d	4-21	II	55**	Fly ash	45**	6 in.	2.16	0.8	2 1-1/2 2-1/2	5.4 4.8 5.0	B-46 B-47 B-48
e	5-19	II	65**	Nat. cem	35**	6 in.	2.33	0.8	1-1/2 3 3-1/4	5.3 5.7 5.2	B-109 B-110 B-111
f	5-6	II	55**	Fly ash	45**	3 in.	2.49	0.8	2-1/2 2-1/2 2	5.7 5.4 5.9	B-77 B-78 B-79
g	5-12	II	65**	Nat. cem	35**	3 in.	2.68	0.8	1/2 2 2	6.0 7.2 6.3	B-93 B-94 B-95

\* Air content of that portion of the concrete containing aggregate smaller than 1-1/2 in. in size.

\*\* Per cent by solid volume.

\* See U. S. Army Engineer Waterways Experiment Station, CE, Investigation of Cement-Replacement Materials; Preliminary Field Investigations (Phase B), Miscellaneous Paper No. 6-123, Report No. 4 (Vicksburg, Miss., April 1956).

(Revised May 1976)

Table 1-CRMI-PB

Section 4

## Record of Testing of Prisms Made for Cement-Replacement Materials Investigation.

Phase B, 1953- (Installed December 1953)

Mix No.	Specimen No.	Port-land Cement %	Max Aggr Size in.	1953-1963 Readings										Beach Row 2	
				0	110	255	422	566	637	787	858	999	1088	1194	
				Cycles 1953 %V <sup>2</sup>	Cycles 1954 %V <sup>2</sup>	Cycles 1955 %V <sup>2</sup>	Cycles 1956 %V <sup>2</sup>	Cycles 1957 %V <sup>2</sup>	Cycles 1958 %V <sup>2</sup>	Cycles 1959 %V <sup>2</sup>	Cycles 1960 %V <sup>2</sup>	Cycles 1961 %V <sup>2</sup>	Cycles 1962 %V <sup>2</sup>	Cycles 1963 %V <sup>2</sup>	
a	B-10	100	6	100	100	106	111	96	101	88	90	85	Failed		
	B-11			100	107	115	114	108	108	104	102	99	75	92	
	B-12			100	106	113	112	105	106	103	98	92	Failed		
b	B-30	100	3	100	94	100	100	92	95	95	97	94	102	97	
	B-31			100	93	97	98	92	94	88	89	93	88	86	
	B-32			100	94	98	97	93	93	88	94	93	90	95	
c	B-61	100	3*	100	88	97	97	91	93	90	93	91	97	99	
	B-62			100	63**	95	94	90	93	87	89	92	88	92	
	B-63			100	62**	97	99	91	93	88	93	91	93	87	
d	B-46	55†	6	100	86	92	79	59	††	††	††	††	Failed		
	B-47			100	90	97	97	85	91	††	††	††	Failed		
	B-48			100	94	99	96	93	96	83	††	††	††	††	
e	B-109	65*	6	100	95	98	99	89	91	74	75	66	Failed		
	B-110			100	93	99	97	88	90	82	83	81	65	82	
	B-111			100	95	100	99	93	96	85	91	89	90	84	
f	B-77	55†	3	100	95	101	104	93	94	††	††	††	††	††	
	B-78			100	106	103	103	94	92	88	††	††	††	††	
	B-79			100	94	101	99	97	89	††	††	††	††	††	
g	B-93	65*	3	100	92	96	102	91	95	86	92	90	90	90	
	B-94			100	94	101	99	98	93	91	95	91	91	90	
	B-95			100	96	100	98	94	90	87	89	88	76	81	

				1964-1975 Readings											
				1329	1492	1622	1778	1963	2117	2270	2439	2596	2736	2782	2894
				Cycles 1964 %V <sup>2</sup>	Cycles 1965 %V <sup>2</sup>	Cycles 1966 %V <sup>2</sup>	Cycles 1967 %V <sup>2</sup>	Cycles 1968 %V <sup>2</sup>	Cycles 1969 %V <sup>2</sup>	Cycles 1970 %V <sup>2</sup>	Cycles 1971 %V <sup>2</sup>	Cycles 1972 %V <sup>2</sup>	Cycles 1973 %V <sup>2</sup>	Cycles 1974 %V <sup>2</sup>	Cycles 1975 %V <sup>2</sup>
a	B-11	100	6	81	75	**	66	73	††	††					
b	B-30	100	3	90	92	82	93	93	89	84	68	68	\$	81	76
	B-31			79	80	65	73	77	69	65	55	NR	\$	74	85
	B-32			88	87	73	86	88	79	72	67	70	\$	88	93
c	B-61	100	3*	93	106	91	95	92	91	86	88	88	\$	116	102
	B-62			94	95	87	86	86	78	74	66	73	\$	103	100
	B-63			89	49	Failed									
d	B-48	55†	6	††	Failed										
e	B-110	65*	6	72	64	57	59	59	20	††					
	B-111			77	74	58	66	67	58	††					
f	B-77	55†	3	††	Failed										
	B-78			††	Failed										
	B-79			††	Failed										
g	B-93	65*	3	95	92	83	92	91	88	79	77	78	\$	88	90
	B-94			82	77	75	71	74	69	65	Failed				
	B-95			69	64	63	58	59	57	54	Failed				

\* Water-cement ratio (by wt), 0.5; that of all other specimens, 0.8.

\*\* These two values are inconsistent with previous and subsequent readings and are presumed incorrect.

† 45% fly ash used as replacement material.

†† End of specimen too rough to obtain satisfactory reading.

\* 35% natural cement used as replacement material.

\*\* Satisfactory pulse velocity reading was not obtained on this prism in 1966; the reading obtained was spurious and was thrown out.

\$ Satisfactory pulse velocity reading was not obtained on this specimen in 1973 due to equipment malfunction.

(Issued August 1977)

Table 1-CRMI-PB (Continued)

Section 4

Record of Testing of Prisms Made for Cement-Replacement Materials Investigation.

Phase B, 1953- (Installed December 1953)

Beach Row 2

Mix No.	Specimen No.	Port- land Cement %	Max Aggr Size in.	1976- Readings	
				3040 Cycles 1976	3117 Cycles 1977
				$\sqrt{V}^2$	$\sqrt{V}^2$
a	B-11	100	6		
b	B-30	100	3	75	70
	B-31			89	61
	B-32			91	101
c	B-61	100	3*	96	108
	B-62			96	97
	B-63				
d	B-48	55†	6		
e	B-110	65‡	6		
	B-111				
f	B-77	55†	3		
	B-78				
	B-79				
g	B-93	65‡	3	88	90
	B-94				
	B-95				

\* Water-cement ratio (by wt), 0.5; that of all other specimens, 0.8.

† 45% fly ash used as replacement material.

‡ 35% natural cement used as replacement material.

(Revised August 1977)

Section 5

Table 1-CERL-FC

Record of Testing of Concrete Beams for CERL Fibrous Concrete ProgramInstalled January 1975

Rack Row 3											
			1975- Readings								
Mix No.	Beam No.	Flaw in.	Jan 1975 0 cycles			Jun 1975 66 cycles		1976 212 cycles		1977 289 cycles	
			%E	fps	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>
0-1	0	0	100	14,150	100	110	161	110	102	110	94
	1	0	100	14,000	100	104	145	109	104	109	87
	2	0	100	13,855	100	105	148	++			
	3	H.L.*	100	13,040	100	**	**	++			
	4	1/16†	100	13,435	100	**	**	++			
	5	1/8	100	13,300	100	**	**	++			
0-2	10	0	100	13,435	100	102	157	103	94	105	94
	11	0	100	13,570	100	100	158	99	100	101	94
	12	0	100	13,435	100	101	165	++			
	13	H.L.	100	13,300	100	101	160	++			
	14	1/16	100	12,545	100	85	176	++			
	15	1/8	100	12,545	100	90	156	++			
0-3	20	0	100	14,150	100	104	153	104	104	108	94
	21	0	100	14,300	100	104	154	105	96	109	94
	22	0	100	14,150	100	101	157	++			
	23	H.L.	100	13,855	100	100	168	++			
	24	1/16	100	13,435	100	79	161	++			
	25	1/8	100	13,570	100	93	150	++			
0-4	30	0	100	13,855	100	101	155	111	96	111	102
	31	0	100	13,570	100	108	154	113	106	115	89
	32	0	100	13,855	100	102	160	++			
	33	H.L.	100	13,435	100	102	153	++			
	34	1/16	100	13,040	100	100	159	++			
	35	1/8	100	12,915	100	78	170	++			
0-5	40	0	100	14,150	100	100	161	114	112	113	98
	41	0	100	14,150	100	103	157	104	107	109	98
	42	0	100	14,000	100	101	174	++			
	43	H.L.	100	13,855	100	97	164	++			
	44	1/16	100	13,170	100	77	172	++			
	45	1/8	100	12,915	100	72	158	++			

\* Hairline crack.

\*\* Unable to obtain reading in June 1975.

† In two pieces.

++ Shipped to CERL in July 1976 for laboratory tests.

(Issued May 1976)

Section 5

CERL Fibrous Concrete Program

In January 1975, 30 concrete beams (3-1/2 by 4-1/2 by 16 in.) were installed at half-tide elevation on the exposure rack at Treat Island, Maine, to determine the effects of the seawater and the freezing and thawing action on the flexural strength and other properties of various fiber concretes. Half the beams were cracked for testing.

The beams were made from five different concrete mixtures (6 beams per mixture); natural coarse (3/8-in. max) and fine aggregate were used in all mixtures. All mixtures were air-entrained (admixture A), and a water-reducing admixture (admixture B) was used in all mixtures. Type III portland cement was used in the amount of 8.0 cwt per cu yd with a water-cement ratio of 0.5 in all mixtures. Concrete mixture data are tabulated below. Table 1-CERL-FC gives the exposure record of the specimens.

Concrete Mixture Data					
Mixture	Type	Fiber Length, in.	Slump, In.	Air Content %	Fiber Ratio by Wt
0-1	A	1/2	0	10.0	0.01
0-2	B	1	1	8.0	0.02
0-3	C	1	8	3.5	0.05
0-4	D	--	0	4.5	0.05
0-5	E	2-1/2	7	2.5	0.05

Prestressed Concrete Program

The purpose of this installation is to develop information on the effect of prestressing on the durability of concrete beams.

In October 1958, 16 prestressed (pretensioned) concrete beams (4-1/2 by 9 by 81 in.) were installed at half-tide elevation on the beach at Treat Island. Each beam contains nine nominal 1/4-in. (1 by 7) strands of high-strength steel wire. In 14 of the 16 beams the strands were tensioned to approximately 70% of their ultimate strength prior to placement of the concrete around them (approximately 3 tons each strand); the strands in the other two beams were not tensioned. Each of these 16 beams contains four sets of gage points with which strains are measured. Twelve of the 16 beams are loaded flexurally (third-point) in pairs. Two intensities of loading are used; in one case the compression due to prestressing is just balanced (100%), and in the other case the compression is exceeded so that approximately 200-psi tension exists in the bottom fibers of the beams (108%). The other four beams are nonloaded controls.

The concrete mixtures represented both air-entrained (admixture II) and nonair-entrained concrete of the following characteristics:

Water-cement Ratio gal/bag	Cement	Nominal Compressive Strength psi	Slump, in.	Cement Factor bags/cu yd
5.85-6.22	Type III (high-early)	6000	1-3/4 ± 1/2	6.1-6.3

The aggregates used were manufactured limestone sand and limestone rock (3/4-in. maximum size).

Table 1-PR lists these specimens and gives their exposure record along with other pertinent information.

Eight additional prestressed beams (4-1/2 by 9 by 81 in.) are exposed in the laboratory as control beams (loaded and nonloaded).

In addition, in October 1958, 72 conventional concrete beams (3-1/2 by 4-1/2 by 16 in.) were installed on the Treat Island exposure rack to determine the field durability of the concrete mixes. These beams were fabricated from the same concrete batches (3 beams from each of 24 batches) as the large beams, and therefore have the same mixture characteristics.

## Section 6

(Issued June 1959)

Table 2-PR lists these specimens and gives their exposure record along with other pertinent information.

Companion specimens to the small beams (3-1/2 by 4-1/2 by 16 in.) were subjected to freezing-and-thawing tests in the laboratory. The results of these tests are given below:

<u>Batch No.</u>	<u>Avg %E at 300 Cycles</u>	<u>Batch No.</u>	<u>Avg %E at 300 Cycles</u>
1	92	13	93
2	89	14	90
3	64	15	4
4	86	16	3
5	91	17	91
6	86	18	70
7	89	19	91
8	84	20	91
9	89	21	87
10	95	22	89
11	88	23	5
12	93	24	5

St. Augustine Installation (1959)

In October 1959, three prestressed (pretensioned) concrete beams (4-1/2 by 9 by 81 in.) were installed on the exposure rack at St. Augustine, Fla. Each beam contains nine nominal 1/4-in. (1 by 7) strands of high-strength steel wire. The strands in all three beams were tensioned to approximately 70% of their ultimate strength prior to placement of the concrete around them (approximately 3 tons per strand). Each beam also contains four sets of gage points for length change measurements. At installation, two of the beams were yoked together and loaded flexurally (third point) until cracks appeared in both beams. The other beam is an unloaded control.

The concrete mixture used in these beams was air-entrained (admixture M) concrete of the following characteristics:

Cement	Air Content %	Water-cement Ratio gal/bag	Nominal Compressive Strength psi	Slump, in.	Cement Factor bags/cu yd
Type III (high-early)	4.3-4.8	5.85	6000	1-3/4 $\pm$ 1/2	6.00-6.03

The aggregates used were manufactured limestone sand and limestone rock (3/4-in. maximum size).

Table 3-PR lists these specimens and gives their exposure record.

Posttensioned Phase (1961 Installation)

The primary purpose of this installation is the exposure testing of end anchorages and end-anchorage protection for several systems of post-tensioning. While not being introduced as variables the following additional effects will be observed and studied in the beam specimens:

- a. Durability of thin web sections
- b. Behavior of grout
- c. Exposure effects on posttensioning steel and conventional reinforcing steel
- d. Effect of eccentricity of loading

## Section 6

(Issued May 1962)

In June 1961, 20 posttensioned beams (nominal size, 10- by 16- by 96-in.) were installed at half-tide elevation on the beach at Treat Island. These beams represent four typical posttensioning systems: Systems A and B (six beams each), Systems C and D (four beams each). Each beam contains one sheathed steel tendon\* which was stressed in accordance with the recommendations of the particular system. The end-anchorage components of all beams are provided with 1-1/2 in. of cover. This cover consists of either air-entrained concrete, sand-cement mortar, or epoxy concrete.

The concrete beams are made of air-entrained concrete and in addition to the posttensioning steel, contain steel for reinforcing. This reinforcing has been provided with  $3/4 \pm 1/4$  in. of cover.

The concrete mixtures in the test beams proper (excluding grout and anchorage protection) have the following characteristics:

Cement	Air Content %	Water-cement Ratio (by wt)	Nominal Compressive Strength psi	Slump, in.	Cement Factor bags/cu yd
Type III (high-early)	4.0-5.0	0.52 (5.85 gal/bag)	6000	1-1/2 to 2	5.98-6.05

The aggregates used in the test beams proper were manufactured limestone sand and limestone rock (3/4-in. maximum size).

The concrete mixtures used for end-anchorage protection contained the same aggregates and have the following characteristics:

Cement	Air Content %	Water-cement Ratio (by wt)	Nominal Compressive Strength psi	Slump, in.	Cement Factor bags/cu yd
Type III (high-early)	3.5-5.0	0.80 (9.03 gal/bag)	3000	1-1/4 to 2	3.90-3.96

The sand-cement mortar used for end-anchorage protection contained manufactured limestone sand and had the following characteristics:

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\* All tendons except that of beam 13 were grouted.

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<u>Cement</u>	<u>Water-cement Ratio (by wt)</u>	<u>28-day Compressive Strength psi</u>	<u>Cement Factor bags/cu yd</u>
Type III (high-early)	0.44 (4.97 gal/bag)	6930-10,400	10.90

The epoxy concrete used for end-anchorage protection contained the same limestone aggregates and had the following characteristics:

<u>Cement</u>	<u>Max Aggr Size, in.</u>	<u>Mixture Proportions (by wt)</u>		<u>28-day Compressive Strength psi</u>
		<u>Epoxy Binder</u>	<u>Coarse Sand:Aggregate</u>	
None	3/4	2.83:7.00:10.00		9320-11,320

The steel tendon in 19 of the 20 test beams was pressure-grouted after posttensioning using a grout of the following characteristics:

<u>Cement</u>	<u>Water-cement Ratio (by wt)</u>	<u>7-day Compressive Strength psi</u>	<u>3-day Expansion %</u>
Type III (high-early)	0.40-0.49 (4.51-5.53 gal/bag)	3640-7400	0-7

The grout used for beam 14 contained a natural sand (100% passing No. 30 sieve). All grouts contained a small amount of aluminum powder.

This program of investigation is being conducted in cooperation with the Reinforced Concrete Research Council, and the test beams and variables were designed in accordance with their recommendations.

Tables 4-PR, 5-PR, and 6-PR give additional information and exposure records of these beams.

Reports Published

Four U. S. Army Engineer Waterways Experiment Station reports concerned with the prestressed concrete program have been issued since 1958. These reports are listed below:

- a. Roshore, E. C., "Durability and Behavior of Prestressed Concrete Beams; Pretensioned Concrete Investigation, Progress to July 1960," Technical Report No. 6-570, Report 1, June 1961, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.
- b. \_\_\_\_\_, "Durability and Behavior of Pretensioned-Prestressed Concrete Beams," Miscellaneous Paper No. 6-611, December 1963, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.
- c. \_\_\_\_\_, "Durability of Prestressed Concrete Beams," Miscellaneous Paper No. 6-665, July 1964, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.
- d. \_\_\_\_\_, "Durability and Behavior of Prestressed Concrete Beams; Posttensioned Concrete Investigation, Progress to July 1966," Technical Report No. 6-570, Report 2, March 1967, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

(Revised Sept 1968)

Table 1-PR

Section 6

## Record of Testing of Large, Prestressed Beams

## Treat Island Exposure

1958- (Installed October 1958)

Beach Row 2 (W to E)

Beam* No.	Type Concrete	Strands Pretensioned	Loaded Flexurally, %	1958-1961 Readings							
				0 Cycles 1958		150 Cycles, 1959		221 Cycles, 1960		362 Cycles, 1961	
				Pulse Veloc fps	$\%v^2$	$\%v^2$	Condition†	$\%v^2$	Condition†	$\%v^2$	Condition†
3**	Air	No	0	15,100	100	106	2	108	1	104	3
4	Air	No	0	15,235	100	106	1	107	1	105	4
7**	Air	Yes	0	15,270	100	102	1	103	2	103	4
8	Air	Yes	0	15,205	100	104	1	107	2	105	4
11**	Air	Yes	108	15,235	100	106	1	105	1	106	4
12	Air	Yes	108	15,135	100	105	1	106	2	106	4
13**	Air	Yes	108	15,170	100	104	1	104	2	109	4
14	Air	Yes	108	15,555	100	104	1	104	2	104	4
15	Plain	Yes	108	15,375	100	Failed					
16	Plain	Yes	108	15,375	100	Failed					
19**	Air	Yes	100	14,965	100	107	1	107	2	107	4
20	Air	Yes	100	15,205	100	106	1	108	1	105	4
21	Air	Yes	100	15,340	100	106	1	107	2	105	3
22**	Air	Yes	100	15,270	100	106	1	104	1	104	3
23	Plain	Yes	100	15,445	100	Failed					
24	Plain	Yes	100	15,590	100	Failed					

Beam* No.	Type Concrete	Strands Pretensioned	Loaded Flexurally, %	1962-1965 Readings							
				451 Cycles 1962		557 Cycles 1963		692 Cycles 1964		855 Cycles 1965	
				$\%v^2$	Condition†	$\%v^2$	Condition†	$\%v^2$	Condition†	$\%v^2$	Condition†
3**	Air	No	0	105	3	111	4	100	9	103	††
4	Air	No	0	104	4	111	4	157	11	105	
7**	Air	Yes	0	102	4	109	4	102	18	109	
8	Air	Yes	0	97	3	105	4	100	12	72	
11**	Air	Yes	108	99	3	107	4	99	4	104	
12	Air	Yes	108	96	3	107	4	100	4	105	
13**	Air	Yes	108	98	3	107	4	101	6	110	
14	Air	Yes	108	94	3	104	4	103	3	104	
19**	Air	Yes	100	98	3	110	4	103	4	108	
20	Air	Yes	100	97	3	104	3	108	3	102	
21	Air	Yes	100	94	3	105	3	99	3	105	
22**	Air	Yes	100	96	3	119	4	100	5	99	

(Continued)

\* For purposes of comparison with the results of tests of the small beams listed in table 2-PR, it should be noted that the beam numbers of the large beams are also their batch numbers.

\*\* In June 1963 epoxy pads were removed from both ends of one beam in each pair. This was done to equalize exposure conditions as some epoxy pads had become disengaged.

† The condition of these specimens is adjudged either annually or biennially by a panel of observers. The beams are examined carefully for cracks, cracks bordered by iron stain, degree of surface scaling (light, moderate, or heavy), rust spots, etc., and a numerical value of condition is assigned to each beam based on the severity of the defects observed. A numerical value of 0 denotes perfect condition; all beams had a condition rating of 0 when they were installed. The higher the condition numerical rating, the greater the deterioration. When a beam breaks in two due to load or accumulates a condition rating of 100 it is considered to have failed.

†† In 1965 the condition of the specimens was not rated by a panel of observers.

(Revised Jan 1973)

Table 1-PR (Continued)

Section 6

Beam No.	Type Concrete	Strands Pretensioned	Loaded Flexurally %	1966-1967 Readings							
				985 Cycles, 1966				1141 Cycles, 1967			
				$\%V^2$		Condition		$\%V^2$		Condition	
				Before Unloading**		Not Loaded		After Reloading		Condition	
3	Air	No	0	*	11			101			§§
4	Air	No	0		20			100			
7	Air	Yes	0		24			105			
8	Air	Yes	0		24			103			
11	Air	Yes	108		4	Failed (Condition rating = 100)					
12	Air	Yes	108		5	104		(Not reloaded)§			
13	Air	Yes	108		5	106		100			
14	Air	Yes	108		4	107		100			
19	Air	Yes	100		6	Failed (Condition rating = 100)					
20	Air	Yes	100		18	107		(Not reloaded)§			
21	Air	Yes	100		6	106		101			
22	Air	Yes	100		4	106		99			

Beam No.	Type Concrete	Strands Pretensioned	Loaded Flexurally %	1968-1971 Readings							
				1326 Cycles, 1968				1480 Cycles, 1969			
				$\%V^2$		Condition		$\%V^2$		Condition	
				1633 Cycles, 1970		1802 Cycles, 1971		$\%V^2$		Condition	
3	Air	No	0	104	11	101	8	98	5	89	5
4	Air	No	0	103	34	(Returned to laboratory in 1968)					
7	Air	Yes	0	100	36	100	34	96	27	Failed	100
8	Air	Yes	0	104	36	(Returned to laboratory in 1968)					
12	Air	Yes	108	89	6	95	7	94	14	86	20
13	Air	Yes	108	Failed	100						
14	Air	Yes	108	99	4	91	7	89	7	78	12
20	Air	Yes	100	96	19		27		73	Failed	100
21	Air	Yes	100	100	6	96	4	93	5		6
22	Air	Yes	100	100	4	92	4	90	5	72	6

\* Satisfactory pulse velocity readings were not obtained in 1966 due to malfunction of testing equipment. (Sheet 2)

\*\* Channel iron on all loaded beams was replaced with stainless steel channel in June 1967. Pulse velocity readings were therefore taken on all loaded beams before unloading and after reloading with stainless steel channel.

§ Due to failure of companion beam.

§§ In 1967 the condition of the specimens was not rated by a panel of observers.

|| End of specimen was too rough to obtain satisfactory pulse velocity reading.

|| || Reading could not be obtained.

(Issued Jan 1973)

Table 1-PR (Concluded)

Section 6

Beach Row 2 (W to E)

Beam No.	Type Concrete	Strands Pretensioned	Loaded Flexurally %	1972 Reading	
				1959 Cycles, 1972 $\frac{1}{2}V^2$	Condition
3	Air	No	0	#	#
12	Air	Yes	108		
14	Air	Yes	108		
21	Air	Yes	100		
22	Air	Yes	100		

(Revised Sept 1967)

Table 2-PR

Section 6

## Record of Testing of Small, Conventional Beams Made from Same Concrete Batches as Large Beams

Treat Island Exposure

1958- (Installed October 1958)

Exposure Rack, Row 3 (W to E)

Beam No.	Batch No.	Type Concrete	1958- Cycles					Readings				
			0 1958 %E	150 1959 %E	221 1960 %E	362 1961 %E	451 1962 %E	557 1963 %E	692 1964 %E	855 1965 %E	985 1966 %E	1141 1967 %E
6770	1	Air	100	108	109	102	105	106	104	104	104	104
6772			100	105	102	97	101	102	99	99	101	102
6774			100	104	103	98	102	101	100	100	101	103
6776	2	Air	100	103	101	95	98	98	97	96	94	94
6778			100	108	105	99	102	103	100	100	100	99
6780			100	109	106	100	103	103	99	100	101	101
6782	3	Air	100	106	103	98	98	98	100	99	98	100
6784			100	107	105	99	105	106	100	100	99	99
6786			100	108	105	98	103	103	100	99	99	100
6788	4	Air	100	104	102	96	100	98	97	96	97	96
6790			100	106	105	99	101	103	99	100	101	103
6792			100	108	106	100	103	103	101	102	103	104
6804	5	Air	*									
6806			100	107	105	99	103	103	99	100	100	101
6808			100	107	105	99	102	96	98	99	97	98
6810	6	Air	*									
6812			100	106	103	97	100	99	95	94	94	95
6814			100	105	103	98	101	101	104	101	97	98
6816	7	Air	100	109	103	95	97	97	94	93	91	91
6818			100	106	101	93	93	93	91	90	88	89
6820			100	104	100	91	92	91	87	86	86	87
6822	8	Air	100	104	101	95	98	96	96	94	94	93
6824			100	101	99	93	95	88	91	91	90	91
6826			100	104	102	96	97	91	89	88	86	86
6828	9	Air	100	108	105	99	99	101	97	93	95	95
6830			100	104	101	94	107	97	92	92	90	92
6832			100	108	106	99	101	100	96	94	93	92
6834	10	Air	100	106	104	97	99	98	95	94	93	93
6836			100	105	103	97	99	98	96	94	96	96
6838			100	109	107	101	104	106	102	100	101	100
6846	11	Air	100	109	106	100	103	103	101	101	101	101
6848			100	106	104	98	100	100	94	94	92	90
6850			100	107	105	98	99	101	94	95	93	93
6852	12	Air	100	108	104	97	101	99	99	97	97	97
6854			100	107	104	98	102	100	98	97	97	97
6856			100	106	104	98	100	99	96	95	94	93
6858	13	Air	100	106	103	96	98	96	95	93	91	91
6860			100	107	104	97	100	99	96	94	94	92
6862			100	107	105	99	103	104	102	102	103	101
6864	14	Air	100	106	104	100	102	102	101	99	101	99
6866			100	108	105	99	103	102	100	100	98	98
6868			100	108	105	99	102	102	101	99	99	99
6870	15	Plain	100	107	106	100	103	101	96	92	92	93
6872			100	104	102	97	97	101	101	100	98	98
6874			100	105	104	98	101	101	97	96	100	94
6876	16	Plain	100	105	102	92	95	94	90	90	88	89
6878			100	104	102	94	96	96	95	91	91	93
6880			100	106	108	101	101	98	102	96	98	98
6882	17	Air	100	107	105	99	103	101	101	101	101	100
6884			100	107	106	99	102	102	101	101	102	102
6886			100	108	105	100	103	103	101	102	101	101
6888	18	Air	100	107	105	100	104	102	101	101	101	102
6890			100	106	106	100	101	103	101	100	101	101
6892			100	109	107	101	104	107	104	104	100	99

(Continued)

\* Lost overboard.

(Sheet 1)

(Revised August 1977)

Table 2-PR (Continued)

Section 6

Beam No.	Batch No.	Type Concrete	Exposure Rack, Row 3 (W to E)									
			1958-1967 Readings									
			0 Cycles 1958 %E	150 Cycles 1959 %E	221 Cycles 1960 %E	362 Cycles 1961 %E	451 Cycles 1962 %E	557 Cycles 1963 %E	692 Cycles 1964 %E	855 Cycles 1965 %E	985 Cycles 1966 %E	1141 Cycles 1967 %E
6894	19	Air	100	104	103	97	99	101	97	97	97	93
6896			100	103	101	95	98	92	97	95	96	95
6898			100	107	105	99	103	105	103	101	102	102
6900	20	Air	100	107	105	99	104	105	104	103	108	108
6902			100	108	105	99	104	105	104	103	104	103
6904			100	107	105	99	102	102	102	101	103	103
6906	21	Air	100	105	103	98	101	102	96	98	100	100
6908			100	105	104	98	101	102	99	100	101	101
6910			100	105	103	98	101	104	101	101	97	99
6912	22	Air	100	105	103	98	102	104	103	102	102	103
6914			100	102	101	96	99	100	100	100	100	102
6916			100	105	103	98	101	102	100	100	100	101
6918	23	Plain	100	108	107	99	97	91	86	87	84	87
6920			100	109	107	95	88	80	70	65	43	Failed
6922			100	105	104	99	100	101	104	106	106	108
6924	24	Plain	100	108	106	101	103	106	106	106	106	107
6926			100	103	100	95	95	93	95	92	90	94
6928			100	106	103	95	92	93	86	82	48	Failed

Beam No.	Batch No.	Type Concrete	1968- Readings									
			1326 Cycles 1968 %E	1480 Cycles 1969 %E	1633 Cycles 1970 %E	1802 Cycles 1971 %E	1959 Cycles 1972 %E	2099 Cycles 1973 %E	2235 Cycles 1974 %E	2347 Cycles 1975 %E	2493 Cycles 1976 %E	2570 Cycles 1977 %E
6770	1	Air	104	102	99	95	95	104	106	108	119	130
6772			99	100	98	95	95	141	147	147	158	108
6774			99	101	101	99	98	145	145	146	144	144
6776	2	Air	92	94	90	88	88	93	101	103	99	103
6778			99	98	94	92	90	94	99	102	98	104
6780			102	98	96	91	90	101	100	101	99	110
6782	3	Air	98	98	96	91	91	91	93	95	95	95
6784			98	96	96	91	89	91	92	94	94	110
6786			98	98	97	95	94	90	92	96	93	92
6788	4	Air	95	95	93	95	94	89	89	92	89	92
6790			101	101	99	101	99	95	103	103	107	109
6792			101	105	103	98	100	100	102	106	108	100
6806	5	Air	99	99	97	90	91	89	91	91	96	98
6808			93	96	96	90	94	89	94	95	97	84
6812	6	Air	88	93	91	91	82	82	85	86	84	80
6814			94	98	98	88	90	92	92	93	90	74
6816	7	Air	90	87	89	83	87	78	80	80	75	70
6818			86	84	86	84	84	79	79	79	74	59
6820			84	82	84	82	83	75	72	74	62	87
6822	8	Air	91	86	88	88	87	87	89	89	82	64
6824			87	83	87	74	74	83	84	86	80	79
6826			83	83	82	88	89	76	76	79	80	80
6828	9	Air	91	89	89	79	81	83	80	82	75	60
6830			88	84	86	74	73	71	71	73	53	136
6832			88	84	86	85	86	86	79	81	77	117
6834	10	Air	92	88	90	92	90	84	85	85	78	88
6836			94	91	93	87	90	85	85	89	81	90
6838			100	97	98	95	94	90	90	92	90	86
6846	11	Air	100	95	97	88	87	85	87	89	87	82
6848			90	88	90	84	83	76	78	78	78	90
6850			92	88	90	90	89	87	89	90		
6852	12	Air	96	93	96	89	89	92	92	92	88	97
6854			94	94	93	90	89	86	87	89	92	89
6856			90	92	91	82	83	84	82	83	89	105

(Continued)

(Sheet 2)

(Revised August 1977)

Table 2-PR (Continued)

Section 6

Beam No.	Batch No.	Type Concrete	Exposure Rack, Row 3 (W to E)									
			1968- Readings									
			1326 Cycles 1968	1480 Cycles 1969	1633 Cycles 1970	1802 Cycles 1971	1959 Cycles 1972	2099 Cycles 1973	2235 Cycles 1974	2347 Cycles 1975	2493 Cycles 1976	2570 Cycles 1977
			%E	%E	%E	%E	%E	%E	%E	%E	%E	%E
6858	13	Air	90	90	90	87	87	85	86	88	88	89
6860			91	90	92	99	99	88	87	88	88	90
6862			102	101	99	96	96	102	104	104	107	109
6864	14	Air	99	96	97	90	91	95	94	96	93	93
6866			98	98	96	90	91	90	90	91	90	85
6868			97	96	95	97	92	90	91	93	89	90
6870	15	Plain	87	85	84	Failed						
6872			97	95	93	Failed						
6874			92	90	91	Failed						
6876	16	Plain	79	77	Failed							
6878			79	76	Failed							
6880			82	79	Failed							
6882	17	Air	99	97	Disappeared from exposure rack							
6884			102	100	Disappeared from exposure rack							
6886			100	96	98	97	96	99	99	100	92	99
6888	18	Air	102	100	97	95	94	96	96	97	97	98
6890			100	101	99	94	93	94	95	95	95	82
6892			102	101	104	103	102	106	107	107	103	109
6894	19	Air	95	92	90	88	87	89	91	92	73	80
6896			96	96	88	87	85	86	87	87	53	111
6898			103	101	103	100	98	109	109	108	119	84
6900	20	Air	108	107	105	101	98	110	110	111	120	109
6902			105	103	102	100	99	109	104	107	107	108
6904			101	98	101	110	111	117	116	117	121	115
6906	21	Air	96	92	96	107	109	114	114	114	124	103
6908			100	102	99	105	106	113	113	114	118	118
6910			101	100	95	107	111	109	117	116	119	113
6912	22	Air	103	103	101	109	108	110	111	111	113	103
6914			102	100	98	108	106	113	112	112	114	128
6916			101	102	100	114	113	114	115	115	117	117
6918	23	Plain	76	74	74	94	95	115	113	114	111	112
6922			107	Failed								
6924	24	Plain	106	Failed								
6926			92	Failed								

(Revised Jan 1972)

Table 3-PR

Section 6

Record of Testing of Large, Prestressed Beams

St. Augustine Exposure

1959- (Installed October 1959)

Beam No.*	Type Concrete	Strands Pre-tensioned	Loaded Flex-urally %	Pulse Velocity fps	1959		1960	
					$\%V^2$	Max Crack Width 1/1000 in.	$\%V^2$	Max Crack Width 1/1000 in.
6	Air	Yes	0	14,900	100	0	107	0
10	Air	Yes	189	15,065	100	10	102	10
18	Air	Yes	189	14,935	100	5	106	5

Beam No.*	Type Concrete	Strands Pre-tensioned	Loaded Flex-urally %	$\%V^2$	1962		1964		1966	
					$\%V^2$	Max Crack Width 1/1000 in.	$\%V^2$	Max Crack Width 1/1000 in.	$\%V^2$	Max Crack Width 1/1000 in.
6	Air	Yes	0	109	0	0	106	0	106	0
10	Air	Yes	189	101	8	8	99	10	109	20
18	Air	Yes	189	106	5	5	105	15	108	40

Beam No.*	Type Concrete	Strands Pre-tensioned	Loaded Flex-urally %	$\%V^2$	1968		1970		1971	
					$\%V^2$	Max Crack Width 1/1000 in.	$\%V^2$	Max Crack Width 1/1000 in.	$\%V^2$	Max Crack Width 1/1000 in.
6	Air	Yes	0	87	0	0	94	0		0†
10	Air	Yes	189**	93†	20†					
18	Air	Yes	189**	91†	45 (Failed in 1968)†					

\* Beam numbers of these large beams are also their batch numbers.

\*\* In 1968, during reloading operation, beam 18 failed, releasing the load on both specimens. This pair could therefore not be reloaded to proper load.

† Returned to laboratory in the spring of 1969.

‡ Testing has been discontinued.

(Revised Sept 1970)

Section 6

Table 4-PR  
General Information, Posttensioned Beams at Treat Island  
(Installed June 1961)

Beam No.	Post-tensioning System	Eccentricity in.	Total Post-tensioning Force, lb	Type of End Protection (See Notes)	
				Landward End	Seaward End
1	A	0	84,000	Flush (1)	Ext (5)
2	A	0	85,000	Ext (4)	Ext (2)
3	A	3	80,000	Ext (3)	Ext (1)
4	A	2	83,000	Ext (7)	Flush (7)
5	A	2	82,000	Ext (6)	Flush (6)
6	A	1	84,000	Flush (9)	Ext (8)
7	B	0	70,000	Ext (1)†	Flush (1)
8	B	2	70,000	Ext (2)	Ext (4)
9	B	3	70,000	Ext (3)†	Ext (5)
10	B	3	70,000	Flush (6)	Ext (6)
11	B	1	70,000	Flush (7)	Ext (7)
12	B	1	70,000	Ext (8)	Flush (9)
13*	C	0	70,000	Ext (1)	Ext (3)
14	C	1	64,000	Ext (2)	Ext (4)
15	C	3	70,500	Ext (5)	Ext (6)
16	C	2	70,000	Ext (7)	Ext (8)
17	D	3	99,000	Ext (1)†	Ext (3)†
18	D	0	99,000	Ext (4)	Ext (2)
19	D	2	99,000	Ext (5)†	Ext (6)†
20	D	1	99,000	Ext (8)	Ext (7)

Note: The end-anchorage protection consists of cover for Flush anchorages and External (Ext) anchorages. In the case of flush anchorages the protection simply fills the recess in the end of the beams. For external anchorages the protection forms an extension of a rectangular section corresponding to the outline of the end blocks at the ends of the beam. The variables are:

- (1) Concrete placed against a cold joint with no surface treatment and no reinforcement. [Ext (1) and Flush (1)]
- (2) Concrete placed against a cold joint with no surface treatment but with reinforcement. [Ext (2)]
- (3) Concrete placed against a bush-hammered surface and with no reinforcement. [Ext (3)]
- (4) Concrete placed against a bush-hammered surface but with reinforcement. [Ext (4)]
- (5) Concrete placed against a surface that has been treated with a retarding agent and no reinforcement. [Ext (5)]
- (6) Concrete bonded to the ends of the beam with an epoxy adhesive and no reinforcement. [Ext (6) and Flush (6)]
- (7) Epoxy concrete without reinforcement. [Ext (7) and Flush (7)]
- (8) Epoxy concrete with reinforcement. [Ext (8)]
- (9) Sand-cement mortar with aluminum powder additive, comparatively dry and well tamped. [Flush (9)]

\* Tendon in this beam was an unbonded coated tendon (not grouted).

† End protection has become detached.

(Revised Sept 1969)

Table 5-PR

Section 6

## Record of Testing of Posttensioned Beams

1961- (Installed June 1961)

Beach Row 2 (W to E)														
Beam No.	0 Cycles, 1961					89 Cycles, 1962			195 Cycles, 1963			330 Cycles, 1964		
	Trans	Pulse	Long.	Pulse	Condition*	$\$V^2$		Condition*	$\$V^2$		Condition*	$\$V^2$		Condition*
	Veloc	Veloc	Veloc	Veloc		Trans	Long.		Trans	Long.		Trans	Long.	
	fps	fps	fps	fps		Trans	Long.		Trans	Long.		Trans	Long.	
1	15,000	100	14,295	100	0	116	116	17	††	118	18	134	111	25
2	17,375	100	15,020	100	0	84	104	11		106	18	213	103	24
3	16,040	100	14,435	100	0	117	108	18		109	23	122	106	24
4	17,670	100	14,435	100	0**	113	112	19		115	20	231	111	24
5	15,795	100	14,735	100	0	117	105	17		110	28	122	104	25
6	17,090	100	14,610	100	0	100	107	12		109	22	146	106	17
7	17,375	100	14,760	100	0**	83	104	7		109	19	196	104	20
8	16,290	100	14,575	100	0†	98	104	20		102	31	140	93	45
9	17,230	100	14,825	100	0**	102	109	18		108	23	176	102	24
10	17,670	100	15,105	100	0**	95	105	14		106	21	173	105	19
11	18,450	100	15,160	100	0**	100	101	8		105	13	182	99	12
12	17,820	100	14,840	100	0**	88	100	16		105	25	152	102	24
13	16,680	100	16,120	100	0**	103	85	11		103	12	152	99	16
14	17,230	100	14,720	100	0**	83	94	25		103	38	157	98	41
15	17,975	100	14,625	100	0**	111	95	15		107	18	178	103	17
16	17,670	100	14,770	100	0**	119	103	10		108	15	156	103	13
17	17,670	100	14,790	100	0	100	78	16		99	46	153	91	50
18	17,820	100	14,020	100	0**	70	81	8		113	16	123	87	22
19	18,785	100	14,950	100	0**	88	107	12		92	15	176	104	41
20	18,615	100	14,765	100	0**	98	105	10		107	15	192	103	16

(Continued)

\* The condition of these specimens is adjudged by a panel of observers either annually or biennially and is expressed numerically. The observers examine and rate the five parts of each beam, which are: part A (landward end anchorage protection), part B (bond between landward end anchorage protection and part C), part C (beam proper including web), part D (bond between seaward end anchorage protection and part C), and part E (seaward end anchorage protection). The surface conditions of parts A, C, and E are rated as to degree (slight, moderate, or heavy) of scaling, spalling, or cracking. Also the number of rust spots, length of reinforcing exposed, number of cracks, etc., are noted. Parts B and D are rated as to the tightness of the bond, if there is a separation, etc. The score of the five parts of the beam is then summed to give a numerical condition rating for the entire beam. A rating of 0 indicates perfect condition and although a score for failure of the entire beam has not as yet been assigned, a score indicating failure would be expressed by a condition rating of the order of 150 to 200. See footnote to table 6-PR for a failing score for beam parts A, B, D, and E.

\*\* These beams were chipped in several places during shipment and placement.

† This beam was chipped in several places during shipment and placement, which resulted in exposure of 3 in. of reinforcing.

†† 1963 transverse readings, 1966 transverse readings, and 1966 longitudinal readings were not satisfactory because of malfunction of testing equipment.

\* In 1965 and 1967 the condition of the specimens was not rated by a panel of observers.

(Sheet 1)

(Revised August 1977)

Table 5-PR (Continued)

Section 6

Beam No.	1118 Cycles, 1969			1271 Cycles, 1970			1440 Cycles, 1971			1597 Cycles, 1972			Beach Row 2 (W to E) 1737 Cycles, 1973		
	$\%V^2$		Condi- tion	$\%V^2$		Condi- tion	$\%V^2$		Condi- tion	$\%V^2$		Condi- tion	$\%V^2$		Condi- tion
	Trans	Long.		Trans	Long.		Trans	Long.		Trans	Long.		Trans	Long.	
1	128	96	26	130	94	31	93	88	26	85	84	28	\$	\$	29
2	98	84	31	89	87	30	60	73	33	62	75	34			37
3	105	87	33	105	90	28	79	73	26	40	66	32			22
4	100	110	26	82	111	39	57	85	36	60	88	30			31
5	112	92	23	103	94	30	73	78	33	41	65	26			21
6	92	100	23	85	101	27	62	75	28	58	70	22			31
7	87	95	31	81	96	49	60	83	48	56	80	54			45
8	108	89	67	95	90	52	71	**	49	63	**	52			47
9	89	60	36	79	62	53	56	**	48	34	**	39			54
10	92	80	29	82	85	29	58	**	31	33	**	34			32
11	87	79	20	76	81	26	61	62	27	43	50	18			12
12	88	64	24	81	64	30	70	77	40	22	65	26			41
13	74	73	30	76	74	27	75	**	30	37	**	21			23
14	85	97	37	82	97	35	63	64	45	48	63	36			46
15	74	98	23	69	100	26	62	69	26	26	69	24			43
16	81	96	21	78	98	22	70	74	20	26	95	26			19
17	72	85	69	76	99	75	64	**	70	45	**	70			70
18	76	75	50	74	88	46	66	63	42	30	76	34			41
19	76	**	68	74	**	71	62	**	65	37	**	69			67
20	78	97	37	83	98	34	54	77	32	56	92	30			41

Beam No.	1873 Cycles, 1974			1985 Cycles, 1975			2131 Cycles, 1976			2208 Cycles, 1977		
	$\%V^2$		Condi- tion	$\%V^2$		Condi- tion	$\%V^2$		Condi- tion	$\%V^2$		Condi- tion
	Trans	Long.		Trans	Long.		Trans	Long.		Trans	Long.	
1	\$	\$	32	§§								
2			40	60	60	46	53	58	47	52	54	52
3			§§									
4			35	*	114	16	**	93	35	**	83	39
5			30	††	113	24	**	104	29	**	101	41
6			40	§§								
7			53	*	85	46	**	84	56	**	74	68
8			54	70	57	44	54	57	59	55	55	75
9			§§									
10			50	62	94	38	32	95	56	29	84	64
11			22	§§								
12			65	65	103	29	57	93	44	57	87	41
13			§§									
14			51	60	67	36	53	68	55	53	64	59
15			§§									
16			41	52	111	18	46	106	40	45	90	44
17			77	§	§	72	**	**	82	**	**	93
18			47	61	86	33	47	87	60	48	80	55
19			§§									
20			42	51	90	32	41	91	50	41	88	55

\*\* A satisfactory reading was not obtained.

§ Satisfactory pulse velocity readings were not obtained in 1973 and 1974.

§§ Shipped back to Concrete laboratory.

(Sheet 2)

(Revised Sept 1968)

Table 6-PR

Section 6

Posttensioned Beams (Installed June 1961)

Summary of Condition of End-Anchorage Protection 1961-

Beach Row 2

Type of End Protection	No. of Beam Ends Used	Average Condition*				
		0 Cycles 1961	89 Cycles 1962	195 Cycles 1963	330 Cycles 1964	493 Cycles 1965
Flush (1)	2	0	0	0	1	**
Flush (6)	2	0	0	0	0	
Flush (7)	2	0	1	1	2	
Flush (9)	2	0	0	0	0	
Ext (1)	4	0	3	6	7	
Ext (2)	4	0	4	6	10	
Ext (3)	4	0	1	4	10	
Ext (4)	4	0	5	6	11	
Ext (5)	4	0	1	1	3	
Ext (6)	4	0	2	4	9	
Ext (7)	4	0	0	0	1	
Ext (8)	4	0	0	0	1	
Total	40					

(Condition)

\* The condition of anchorage protection is adjudged by a panel of observers either annually or biennially; the condition is expressed numerically. The observers examine and rate four of the five parts of each beam: part A (landward end anchorage protection), part B (bond between landward end anchorage protection and beam), part D (bond between seaward end anchorage protection and beam), and part E (seaward end anchorage protection). The condition rating for any one type of end protection is the sum of the scores of parts A and B or parts D and E. A rating of 0 indicates perfect condition while a rating of 28 is equal to failure for an end protection. The average condition rating shown for a given type of end protection is the average score for all protection of that type in this program.

\*\* In 1965 the condition of the specimens was not rated by a panel of observers.

(Sheet 1)

(Revised Jan 1973)

Table 6-PR (Continued)

Section 6

Beach Row 2

Type of End Protection	No. of Beam Ends Used	Average Condition					
		623 Cycles 1966	779 Cycles 1967	964 Cycles 1968	1118 Cycles 1969	1271 Cycles 1970	1440 Cycles 1971
Flush (1)	2	2	††	2	0	0	2
Flush (6)	2	0		0	0	0	0
Flush (7)	2	2		2	4	2	6
Flush (9)	2	2		2	0	0	0
Ext (1)	4	11†		12†	13†	16*	17*
Ext (2)	4	11		12	14	10	12
Ext (3)	4	10†		12†	14†	16*	13*
Ext (4)	4	13		15	15	12	14
Ext (5)	4	2		9†	10†	9†	11†
Ext (6)	4	9†		9†	12†	10†	12†
Ext (7)	4	1		1	4	2	5
Ext (8)	4	4		4	4	4	10
Total	40						

(Continued)

- † One end protection has failed.  
 †† In 1967 the condition of the specimens was not rated by a panel of observers.  
 \* Two end protections have failed.

(Sheet 2)

(Revised August 1977)

Table 6-PR (Continued)

Section 6

Beach Row 2

Type of End Protection	No. of Beam Ends Used	Average Condition					
		1597	1737	1873	1985	2131	2208
		Cycles 1972	Cycles 1973	Cycles 1974	Cycles 1975	Cycles 1976	Cycles 1977
Flush (1)	2	2	1	5	3§	4§	6§
Flush (6)	2	0	0	6	0	1	0
Flush (7)	2	4	2	5	1§	6§	6§
Flush (9)	2	0	0	7	2§	3§	0§
Ext (1)	4	16	17	##			
Ext (2)	4	10	10	12	12	15	12
Ext (3)	4	16	16	##			
Ext (4)	4	12	18	14	13	17	15
Ext (5)	4	10	14	##			
Ext (6)	4	14	17	##			
Ext (7)	4	4	4	6	3§§	4§§	4§§
Ext (8)	4	4	11	14	7§§	9§§	8§§
Total	40						

## Data incomplete; beams were shipped back to concrete laboratory.

§ Based on 1 beam end.

§§ Based on 3 beams ends.

(Sheet 3)

WES Fibrous Concrete Program

In July 1975, 50 concrete beams were installed at half-tide elevation on the exposure rack at Treat Island, Maine, to determine the effects of sea water and freezing and thawing action on the flexural strength and other properties of various fiber concretes.

The beams were made from nine different mixtures. The fine and coarse aggregates were manufactured limestone sand and 3/4-in. maximum limestone, respectively. All mixtures contained a water-reducing admixture (admixture B), and five mixtures contained an air-entraining admixture (admixture A). Type II portland cement was used in the amount of 7.89 cwt per cu yd except for mixtures N and O, which contained 11.0 cwt per cu yd. The water cement ratio was 0.45 for all mixtures.

The number and types of beams exposed are: twelve 6 by 6 by 30 in., twenty-one 6 by 6 by 36 in., and seventeen 9 by 9 by 45 in. The 9 by 9 by 45-in. beams were yoked and stressed by third-point loadings to working loads of 35 percent of ultimate. Table 1-WES-FC gives the exposure record of the specimens. More mixture data are tabulated below:

Concrete Mixture Data					
Mixture	Fiber		Slump, in.	Air Content %	Fiber Ratio by Wt
	Type	Length, in.			
H	None	--	5 3/4	2.5	--
I	C	3/4	2 1/2	1.8	0.04
J	None	--	7	8.5	--
K	C	3/4	4	8.5	0.04
L	A	1	2	1.9	0.04
M	A	1	3	7.0	0.04
N	D	1	1	3.6	0.01
O	D	1	2	7.0	0.01
P	B	1	2 3/4	7.0	0.04

(Revised August 1977)

Table 1-WES-FC

Section 7

Record of Testing of Concrete Beams for WES Fibrous Concrete Program

Installed July 1975

Rack Rows 4 and 6

Beam No.	Load, lb	1975- Readings							
		Jul 1975			1976		1977		
		0 Cycles			146 Cycles		223 Cycles		
		%E	fpa	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	
9- by 9- by 45-in. Beams									
H-3	2720	*	16,095	100	*	103	*	102	
I-1	4340		15,560			97		97	
I-3			16,375			101		98	
J-1			14,315			103		102	
J-3			14,590			106		105	
K-1			14,590			104		102	
K-3			14,260			103		100	
L-1			16,520			94		93	
L-3			16,305			99		101	
M-1			14,590			98		99	
M-3			15,060			101		100	
N-1			14,765			108		103	
N-3			14,705			103		103	
O-1			14,150			108		107	
O-3			14,370			104		105	
P-1			14,940			106		103	
P-2			15,245			109		105	
6- by 6- by 30-in. Beams									
H-7	None	100	16,235	100	98	105	106	103	
H-8			15,725		102	105	109	100	
H-15			15,825		106	107	110	101	
H-16			15,825		102	108	108	99	
I-8			15,925		120	105	116	97	
K-8			14,970		109	109	125	99	
L-7			16,130		94	108	109	100	
L-8			16,130		103	108	103	101	
M-7			14,125		100	102	103	94	
O-8			13,890		100	103	103	101	
O-16			15,245		88	110	97	100	
P-8			14,705		106	105	106	100	
6- by 6- by 36-in. Beams									
I-7	None	100	15,875	100	119	103	96	98	
I-15			16,130		105	109	114	102	
J-7			14,495		103	106	112	99	
J-8			14,495		109	104	118	96	
J-15			14,495		100	104	100	97	
J-16			14,565		115	109	106	103	
K-7			14,780		103	106	109	98	
K-15			14,565		106	106	103	101	
K-16			14,285		102	109	100	102	
L-15			14,635		104	104	108	101	
L-16			14,635		103	103	106	100	
M-8			14,085		205	109	210	99	
M-15			15,075		100	104	109	99	
M-16			14,850		112	109	109	102	
N-7			14,150		118	105	106	109	
N-8			14,085		112	102	124	99	
N-15			14,020		109	106	112	101	
N-16			14,020		100	110	112	102	
O-7			13,825		106	110	109	103	
O-15			12,710		97	108	103	102	
P-7			14,635		109	107	109	98	

\* Loaded beams not tested for %E.

Cement-Replacement Materials Investigation, Phase D\*

In October 1958, 75 concrete cores (10 in. in diameter by 20 in. long) were installed on the Treat Island exposure rack as a part of Phase D of the Cement-Replacement Materials Investigation. The purpose of this installation is to determine the durability of mass concrete of several cement factors containing certain cement-replacement materials. The cores were diamond-drilled from twenty-five 1000-cu-ft mass concrete blocks (3 core sections per block) which were fabricated as a part of this investigation.

Also in October 1958, 20 mass concrete cubes (8 cu ft) were installed at half-tide elevation on the beach at Treat Island. These cubes were companion specimens to 18 of the 25 large blocks, and therefore to 54 of the 75 cores. Cubes numbered 10 and 10A are duplicates, as are 11 and 11A. Successful completion of the laboratory heat studies, for which the cubes were originally made, required that two additional cubes (10A and 11A) be fabricated. This provided the two additional cubes for this field exposure, making a total of 20 cubes instead of 18.

The aggregates used in these concrete specimens were limestone rock (6-in. maximum size) and manufactured limestone sand.

Table 1-CRMI-PD lists the concrete cores and gives their exposure record along with mixture data; table 2-CRMI-PD gives the same information for the concrete cubes.

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\* See U. S. Army Engineer Waterways Experiment Station, CE, Investigation of Cement-Replacement Materials; Performance of Various Materials in Mass Concrete, Field Study (Phase D), Miscellaneous Paper No. 6-123, Report No. 6 (Vicksburg, Miss., May 1957).

(Revised Aug 1963)

Table 1-CRMI-PD

Section 8

## Mixture Data and Record of Testing of Cores from Cement-replacement Materials Investigation,

Phase D, 1958- (Installed October 1958)

											Exposure Rack, Row 4, West to East							
Core No.	Cementitious Mat'l		Nominal Cement Factor bags/cu yd	Water-cement Ratio by Wt*	Air Content %**	1958-1962 Readings												
	Type II Portland Cement %	Replacement Material %				0 Cycles 1958			150 Cycles 1959		221 Cycles 1960		362 Cycles 1961		451 Cycles 1962			
						Fulse Veloc	ft/s <sup>2</sup>	ft/s <sup>2</sup>	ft/s <sup>2</sup>	ft/s <sup>2</sup>	ft/s <sup>2</sup>	ft/s <sup>2</sup>	ft/s <sup>2</sup>					
														ft/s	ft/s	ft/s	ft/s	ft/s
1T	100	0	1-3/4	0.93	6.1-6.6	100	13,950	100	91	105	89	106	80	98	82	102		
1M						100	14,910	100	102	100	102	100	92	93	91	85		
1B						100	14,570	100	95	102	96	101	92	100	90	93		
2T	65	Nat cem	1-3/4	0.96	1.7-8.2	100	14,965	100	80	98	81	100	81	79	58	†		
2M		35				100	14,480	100	84	95	89	97	89	102	77	95		
2B						100	15,675	100	91	93	96	92	89	91	91	90		
3T	70	Cal sh	1-3/4	1.01	5.3-5.8	100	14,920	100	116	95	112	93	105	83	105	†		
3M		30				100	15,725	100	95	88	113	91	96	85	107	†		
3B						100	16,190	100	98	92	101	96	96	92	99	32		
4T	88	Unc D	1-3/4	0.98	5.4-6.4	100	14,875	100	100	95	91	95	83	83	93	†		
4M		12				100	16,580	100	99	89	95	92	90	84	103	72		
4B						100	14,700	100	101	102	100	103	92	100	106	90		
5T	100	0	2-1/4	0.73	3.9-6.1	100	16,020	100	98	98	97	96	89	102	90	52		
5M						100	17,160	100	93	92	94	100	86	90	88	98		
5B						100	15,240	100	103	102	99	113	96	110	97	112		
6T	75	Pumicite	2-1/4	0.77	5.7-7.4	100	14,975	100	100	86	118	89	106	95	110	35		
6M		25				100	16,140	100	99	91	103	95	96	91	90	87		
6B						100	17,835	100	99	80	103	82	97	81	92	77		
7T	50	Slag	2-1/4	0.76	4.7-6.6	100	16,395	100	110	93	107	96	95	96	98	50		
7M		50				100	17,185	100	111	89	102	91	92	89	96	92		
7B						100	17,125	100	104	87	107	97	98	100	100	111		
8T	65	Nat cem	2-1/4	0.76	5.7-6.4	100	15,245	100	108	100	109	101	101	110	94	104		
8M		35				100	16,135	100	91	94	92	96	84	98	87	102		
8B						100	15,195	100	88	110	97	111	87	119	91	119		
9T	70	Cal sh	2-1/4	0.79	5.9-6.3	100	15,385	100	102	93	93	86	Broken in handling					
9M		30				100	15,580	100	78	96	80	98	70	104	76	99		
9B						100	16,080	100	104	89	113	93	102	103	98	91		
10T	88	Unc D	2-1/4	0.80	5.5-6.2	100	15,195	100	101	112	102	120	96	100	90	88		
10M		12				100	15,380	100	93	96	99	102	90	106	87	110		
10B						100	15,435	100	105	95	105	100	98	100	98	101		
11T	70	Fly ash	2-1/4	0.73	5.5-6.2	100	16,345	100	106	93	112	89	105	93	100	†		
11M		30				100	17,805	100	91	80	87	81	84	77	99	49		
11B						100	16,345	100	111	94	115	101	106	106	103	†		
12T	100	0	3	0.55	6.3-7.4	100	14,990	100	104	96	106	114	93	110	97	100		
12M						100	16,140	100	95	93	94	103	89	98	89	118		
12B						100	14,990	100	102	102	102	114	96	115	94	117		
13T	75	Pumicite	3	0.58	6.2-7.6	100	15,480	100	104	93	109	99	106	102	108	77		
13M		25				100	16,395	100	115	100	124	101	112	108	112	113		
13B						100	16,135	100	104	91	106	93	98	98	100	113		
14T	50	Slag	3	0.60	5.8-6.3	100	16,840	100	107	91	110	96	100	96	99	52		
14M		50				100	16,580	100	102	91	106	99	99	92	96	104		
14B						100	17,565	100	105	76	104	77	96	82	97	87		
15T	65	Nat cem	3	0.56	6.5-8.7	100	15,875	100	99	98	100	100	95	100	96	104		
15M		35				100	16,415	100	97	96	99	105	91	100	93	106		
15B						100	16,625	100	91	92	97	97	87	92	88	113		
16T	75	Cal sh	3	0.59	5.7-7.4	100	16,125	100	99	93	99	95	91	98	97	40		
16M		25				100	16,090	100	86	91	87	103	78	102	82	96		
16B						100	15,425	100	100	96	107	105	96	104	94	82		

(Continued)

Note: Nat cem = natural cement; cal sh = calcined shale; unc D = uncalcined diatomite; slag = blast-furnace slag.

\* Ratio of water to cementitious material based on total weight.

\*\* Air content of that portion of the concrete containing aggregate smaller than 1-1/2 in. in size.

† End of specimen too rough to obtain satisfactory reading.

(Sheet 1)

(Revised Sept 1968)

Table 1-CRMI-PD (Continued)

Section 8

Exposure Rack, Row 4 (W to E)																
Core No.	Cementitious Mat'l		Nominal Cement Factor bags/cu yd	Water-Cement Ratio by Wt	Air Content %	1958-1962 Readings										
	Type II Portland Cement %	Replace-ment Material %				0 Cycles 1958			150 Cycles 1959		221 Cycles 1960		362 Cycles 1961		451 Cycles 1962	
						Pulse Veloc	f/s	f/v <sup>2</sup>	f/E	f/v <sup>2</sup>	f/E	f/v <sup>2</sup>	f/E	f/v <sup>2</sup>	f/E	f/v <sup>2</sup>
					f/E	f/v <sup>2</sup>	f/E	f/v <sup>2</sup>	f/E	f/v <sup>2</sup>	f/E	f/v <sup>2</sup>	f/E	f/v <sup>2</sup>		
17T	92	Unc D	3	0.55	5.3-7.4	100	16,560	100	98	96	103	101	99	104	96	121
17M		8				100	17,200	100	92	94	95	96	87	98	83	98
17B						100	15,925	100	95	104	96	103	87	106	88	108
18T	70	Fly ash	3	0.55	6.1-7.7	100	15,675	100	100	100	102	104	93	108	89	110
18M		30				100	16,675	100	101	96	105	100	98	100	96	100
18B						100	16,560	100	111	94	114	97	107	98	108	106
19T	100	0	4	0.42	6.9-7.9	100	16,020	100	103	100	105	100	95	104	95	106
19M						100	16,750	100	97	94	98	103	91	104	90	109
19B						100	16,575	100	100	92	100	97	93	100	92	109
20T	75	Pumicite	4	0.45	5.7-8.5	100	16,445	100	112	93	114	95	107	100	110	106
20M		25				100	16,300	100	110	94	114	106	106	102	107	104
20B						100	16,395	100	110	93	114	96	105	89	107	106
21T	50	Slag	4	0.44	5.4-6.8	100	16,170	100	100	95	110	99	101	100	99	100
21M		50				100	15,375	100	95	102	106	111	100	104	98	106
21B						100	16,720	100	104	94	107	97	99	100	98	98
22T	80	Nat cem	4	0.43	3.9-7.4	100	15,295	100	100	104	68	102	67	102	Bkn in handling	
22M		20				100	16,140	100	92	91	93	107	86	94	86	106
22B						100	16,840	100	97	91	98	96	99	94	94	102
23T	80	Cal sh	4	0.45	4.5-6.1	100	16,185	100	100	93	104	100	95	88	99	58
23M		20				100	16,700	100	97	87	103	98	94	96	95	106
23B						100	16,610	100	101	91	101	97	94	98	94	106
24T	94	Unc D	4	0.42	6.5-7.8	100	15,335	100	102	100	103	107	95	112	96	117
24M		6				100	15,240	100	102	104	106	115	97	112	97	108
24B						100	16,460	100	99	94	100	105	92	100	93	104
25T	70	Fly ash	4	0.44	6.3-8.6	100	15,525	100	105	91	107	95	96	95	94	102
25M		30				100	16,030	100	109	93	114	104	110	100	93	100
25B						100	16,490	100	106	91	109	96	100	96	101	100

						Exposure Rack, Row 4 (W to E)											
						1963-1968 Readings											
						557		692		855		985		1141		1326	
						Cycles 1963	Cycles 1964	Cycles 1965	Cycles 1966	Cycles 1967	Cycles 1968						
						$\bar{E}$	$\bar{V}^2$	$\bar{E}$	$\bar{V}^2$	$\bar{E}$	$\bar{V}^2$	$\bar{E}$	$\bar{V}^2$	$\bar{E}$	$\bar{V}^2$	$\bar{E}$	$\bar{V}^2$
1T	100	0	1-3/4	0.93	6.1-6.6	80	87	80	77	64	+	37F	+				
1M						NR	84	NR	+	NR	+	Failed					
1B						88	103	77	83	68	108	64	70	57	66	57	+
2T	65	Nat cem	1-3/4	0.96	1.7-8.2	41F	+										
2M		35				NR	96	NR	+	74	+	Failed					
2B						NR	76	NR	67	95	103	88	+	82	+	82	+
3T	70	Cal sh	1-3/4	1.01	5.3-5.8	NR	+	NR	+	Failed							
3M		30				109	+	NR	+	NR	+	Failed					
3B						NR	51	67	+	75	+	Failed					
4T	88	UncID	1-3/4	0.98	5.4-6.4	37F	+										
4M		12				NR	+	NR	+	89	+	Failed					
4B						87	103	NR	90	98	+	Failed					
5T	100	0	2-1/4	0.73	3.9-6.1	89	99	87	104	86	108	82	43	75	42	75	98
5M						86	105	86	101	77	107	77	80	71	88	73	73
5B						97	109	88	115	88	127	85	49	64	49	64	95
6T	75	Pumicite	2-1/4	0.77	5.7-7.4	89	33	NR	66	109	+	132	+	Failed			
6M		25				72	88	71	39	54	+	Failed					
6B						NR	66	75	70	79	+	53	+	Failed			
7T	50	Slag	2-1/4	0.76	4.7-6.6	86	41	81	+	79	+	Failed					
7M		50				NR	29	70	66	67	+	Failed					
7B						99	105	87	97	81	97	87	87	73	74	70	71

(Continued)

Note: NR denotes satisfactory reading was not obtained although an attempt was made to obtain a satisfactory reading.  
F denotes specimen failed.

† End of specimen too rough to obtain satisfactory reading.

(Sheet 2)

(Revised Sept 1969)

Table 1-CRMI-PD (Continued)

Section 8

Exposure Rack, Row 4 (W to E)																	
Core No.	Cementitious Mat'l		Nominal Cement Factor bags/cu yd	Water-Cement Ratio by wt	Air Content %	1963-1968 Readings											
	Type II Portland Cement	Replacement Material				557 Cycles 1963		692 Cycles 1964		855 Cycles 1965		985 Cycles 1966		1141 Cycles 1967		1326 Cycles 1968	
	%	%				FE	FE <sup>2</sup>	FE	FE <sup>2</sup>	FE	FE <sup>2</sup>	FE	FE <sup>2</sup>	FE	FE <sup>2</sup>	FE	FE <sup>2</sup>
8T 8M 8B	65	Nat cem 35	2-1/4	0.76	5.7-6.4	97 85 89	109 112 113	79 103 87	105 105 105	77 85 76	113 97 111	85 93 70	65 † 96	76 82 68	64 † 91	Failed 81 68	† † 96
9M 9B	70	Cal sh 30	2-1/4	0.79	5.9-6.3	NR 95	104 98	100 95	95 94	Broken in handling					81	70	76 †
10T 10M 10B	88	Unc D 12	2-1/4	0.80	5.5-6.2	92 81 93	97 94 68	92 89 95	91 99 92	78 78 92	72 104 102	81 75 83	66 65 65	79 72 81	66 69 64	69 69 78	67 75 84
11T 11M 11B	70	Fly ash 30	2-1/4	0.73	5.5-6.2	NR NR 109	† 48 104	97 NR 101	† † 91	92 † 84	Failed Broken in handling				Failed		
12T 12M 12B	100	0	3	0.55	6.3-7.4	87 83 NR	117 107 138	87 83 79	119 103 119	83 77 71	106 91 129	81 77 74	91 84 93	79 68 69	76 87 91	72 71 72	95 89 †
13T 13M 13B	75	Pumicite 25	3	0.58	6.2-7.6	110 111 101	69 115 107	99 115 97	58 110 103	104 106 100	116 103 107	111 106 101	† 93 94	92 103 96	† 93 93	95 101 99	† 94 91
14T 14M 14B	50	Slag 50	3	0.60	5.8-6.3	92 92 93	98 101 74	87 98 91	89 98 NR	82 86 82	81 87 77	83 86 80	68 73 †	80 84 Failed	68 67	Failed 85	†
15T 15M 15B	65	Nat cem 35	3	0.56	6.5-8.7	94 93 91	103 72 92	90 87 86	106 110 99	88 87 83	110 103 100	89 86 81	82 94 73	88 81 80	85 89 89	85 80 76	93 92 74
16T 16M 16B	75	Cal sh 25	3	0.59	5.7-7.4	95 79 91	101 119 109	93 75 78	94 91 NR	83 70 79	103 97 117	87 59 76	72 67 68	82 56 75	69 70	Failed 55	75 78 78
17T 17M 17B	92	Unc D 8	3	0.55	5.3-7.4	96 80 86	102 104 114	84 87 85	108 98 98	82 76 82	99 85 99	85 82 81	89 82 85	82 81 78	73 73 82	76 65 75	84 84 93
18T 18M 18B	70	Fly ash 30	3	0.55	6.1-7.7	93 92 108	107 59 106	86 91 110	109 98 104	87 84 107	113 111 99	84 91 109	† 73 91	82 87 106	† 70 89	73 72 106	† 70 94
19T 19M 19B	100	0	4	0.42	6.9-7.9	93 90 92	101 90 70	90 90 93	111 108 112	83 85 78	89 85 105	83 82 78	87 74 92	79 78 74	90 † 94	78 59 79	98 † 100
20T 20M 20B	75	Pumicite 25	4	0.45	5.7-8.5	110 107 108	107 116 104	110 105 110	107 112 106	107 101 104	107 95 94	102 101 108	87 93 87	99 95 106	89 87 87	96 97 103	93 96 93
21T 21M 21B	50	Slag 50	4	0.44	5.4-6.8	97 NR 95	63 97 93	91 Failed 93	93 102	87 81	89 82	89 81	81 65	79 Failed	77	73	81
22M 22B	80	Nat cem 20	4	0.43	3.9-7.4	87 94	107 109	87 95	109 95	67 93	104 100	67 96	106 †	64 93	108 †	64 96	102 †
23T 23M 23B	80	Cal sh 20	4	0.45	4.5-6.1	90 95 93	118 111 100	84 92 78	95 118 97	58 86 83	110 102 101	63 82 80	82 85 89	60 77 77	80 85 91	60 69 70	80 82 86
24T 24M 24B	94	Unc D 6	4	0.42	6.5-7.8	82 95 93	112 119 114	79 93 95	114 113 109	78 88 89	102 120 103	78 91 88	90 93 86	76 83 82	98 87 94	77 89 ††	100 91 ††
25T 25M 25B	70	Fly ash 30	4	0.44	6.3-8.6	86 96 102	108 107 102	74 89 100	101 111 99	77 78 97	111 104 93	71 71 88	55 79 88	68 67 92	58 83 80	54 54 51	58 84 84

† End of specimen too rough to obtain satisfactory reading.

†† Broken in handling in 1968.

(Sheet 3)

(Revised Aug 1974)

Table 1-CRMI-PD (Continued)

Section 8

Exposure Rack, Row 4 (W to E)															
Core No.	Cementitious Type II Portland Cement %	Mat'l Replacement Material %	Nominal Cement Factor bags/cu yd	Water-Cement Ratio by wt	Air Content %	1969-1973 Readings									
						1480 Cycles 1969		1633 Cycles 1970		1802 Cycles 1971		1959 Cycles 1972		2099 Cycles 1973	
						%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>
1B	100	0	1-3/4	0.93	6.1-6.6	Failed	†								
2B	65	Nat cem 35	1-3/4	0.96	1.7-8.2	Failed	†								
5T 5M 5B	100	0	2-1/4	0.73	3.9-6.1	72 72 63	81 69 85	69 67 61	71 60 81	72 70 60	49 50 34	NR NR 55	62 44 44	NR 72 51	Failed 50 69
7B	50	Slag 50	2-1/4	0.76	4.7-6.6	NR	66	71	62	Failed	†				
8M 8B	65	Nat cem 35	2-1/4	0.76	5.7-6.4	78 67	† 88	82 65	† 82	Failed Failed	† †				
9B	70	Cal sh 30	2-1/4	0.79	5.9-6.3	NR	†	Failed	†						
10T 10M 10B	88	Unc D 12	2-1/4	0.80	5.5-6.2	68 66 76	† 68 71	NR 67 74	† 63 68						
12T 12M 12B	100	0	3	0.55	6.3-7.4	72 70 71	81 84 †	68 69 72	77 72 †	68 63 Failed	52 58 †				
13T 13M 13B	75	Pumicite 25	3	0.58	6.2-7.6	93 99 97	† 91 91	98 108 107	† 78 80	94 104 98	† 54 43	90 98 100	† 49 47	76 85 100	† 57 32
14M	50	Slag 50	3	0.60	5.8-6.3	Failed	†								
15T 15M 15B	65	Nat cem 35	3	0.56	6.5-8.7	85 81 75	88 87 68	84 83 78	77 81 63	77 76 67	47 69 †	74 80 NR	83 77 †	75 72	65 67
16T 16B	75	Cal sh 25	3	0.59	5.7-7.4	74 50F	69 †	73	65	67	†	NR	†		
17T 17M 17B	92	Unc D 8	3	0.55	5.3-7.4	75 65 74	76 73 82	71 66 76	68 65 75	61 64 75	45 43 62	NR 66 84	48 61 68	NR 56 46	Failed 58 58
18T 18M 18B	70	Fly ash 30	3	0.55	6.1-7.7	72 87 104	† 70 91	NR Failed 114	† 48 68						
19T 19M 19B	100	0	4	0.42	6.9-7.9	77 58 76	93 † 98	78 Failed 77	79 † 75	69 73	45 67	72 71	67 56	72 66	86 70
20T 20M 20B	75	Pumicite 25	4	0.45	5.7-8.5	96 96 104	84 93 87	88 102 111	78 83 78	81 93 102	44 61 62	87 88 97	42 61 60	48 84 97	40 79 71
21T	50	Slag 50	4	0.44	5.4-6.8	73	67	NR	48	69	†	Failed	†		
22M 22B	80	Nat cem 20	4	0.43	3.9-7.4	62 95	106 †	61 NR	93 †	59 90	75 †	Failed Failed	† †		
23T 23M 23B	80	Cal sh 20	4	0.45	4.5-6.1	59 69 69	† 84 86	59 73 68	† 74 81	53 60 66	† 46 32	Failed 57 65	† 29 40	52 52	76 69
24T 24M 24B	94	Unc D 6	4	0.42	6.5-7.8	75 87 ††	88 87 ††	77 87	82 81	75 88	35 37	77 85	34 69	75 82	90 78
25T 25M 25B	70	Fly ash 30	4	0.44	6.3-8.6	50F 50F Failed	91 † †								

† End of specimen too rough to obtain satisfactory reading.

†† Broken in handling in 1968.

NR Satisfactory reading was not obtained although an attempt was made to obtain one.

F Denotes specimen has failed.

(Sheet 4)

(Revised August 1977)

Table 1-CRMI-PD (Continued)

Section 8

Core No.	Cementitious Mat'l		Nominal Cement Factor bags/cu yd	Water-Cement Ratio by wt	Air Content %	Exposure Rack, Row 4 (W to E)							
	Type II Portland Cement %	Replacement Material %				1974-1977 Readings							
						2235 Cycles 1974		2347 Cycles 1975		2493 Cycles 1976		2570 Cycles 1977	
						%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>
						5M 5B	100	0	2-1/4	0.73	3.9-6.1	70 NR	53 69
12T 12M	100	0	3	0.55	6.3-7.4	62 48	92 68	62 NR	93 96	60 Failed	73	46	65
13T 13M 13B	75	Pumicite 25	3	0.58	6.2-7.6	73 NR 96	+ 66 89	-- Failed 96	-- Failed 113	Failed NR			
15T 15M	65	Nat cem 35	3	0.56	6.5-8.7	70 63	91 94	70 62	94 120	68 60	94 67	60 51	88 71
17M 17B	92	Unc D 8	3	0.55	5.3-7.4	50 77	64 95	Failed 78	Failed 117	69 77	77	80	NR
18B	70	Fly ash 30	3	0.55	6.1-7.7	106	100	106	123	88	77	49	68
19T 19B	100	0	4	0.42	6.9-7.9	68 67	96 94	69 66	120 135	96 49	79 78	87 Failed	73
20T 20M 20B	75	Pumicite 25	4	0.45	5.7-8.5	48 84 97	67 76 79	51 84 102	51 96 115	NR 71 68	49 86 80	Failed 36 89	67 64
23M 23B	80	Cal sh 20	4	0.45	4.5-6.1	52 52	66 73	55 51	116 94	55 42	91 93	Failed 67	78
24T 24M	94	Unc D 6	4	0.42	6.5-7.8	75 82	91 93	72 84	116 131	61 94	104 90	61 61	87 81

† End of specimen too rough to obtain satisfactory reading.

NR Satisfactory reading was not obtained although an attempt was made to obtain one.

(Sheet 5)

AD-A075 359

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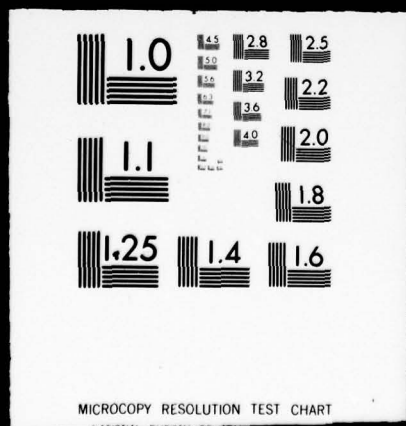
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(Revised Sept 1968)

Table 2-CRMI-PD

Section 8

Mixture Data and Record of Testing of Cubes from Cement-Replacement Materials Investigation,Phase D, 1958- (Installed October 1958)

Beach Row 1 (W to E)													
Cube No.	Cementitious Mat'l		Nominal Cement Factor bags/cu yd	Water-Cement Ratio by Wt*	Air Content %**	1958-1963 Readings							
	Type II Portland Cement %	Replacement Material %				0 Cycles 1958		150 Cycles 1959 $\bar{V}^2$	221 Cycles 1960 $\bar{V}^2$	362 Cycles 1961 $\bar{V}^2$	451 Cycles 1962 $\bar{V}^2$	557 Cycles 1963 $\bar{V}^2$	
						Pulse Veloc fps	$\bar{V}^2$						
1	100	0	1-3/4	0.93	6.1-6.6	15,625	100	93	88	81	84	†	
2	65	Nat cem 35	1-3/4	0.96	1.7-8.2	14,185	100	96	105	103	109	52	
3	70	Cal sh 30	1-3/4	1.01	5.3-5.8	15,150	100	97	103	103	106	50	
4	88	Unc D 12	1-3/4	0.98	5.4-6.4	15,265	100	98	104	112	104	112	
5	100	0	2-1/4	0.73	3.9-6.1	16,000	100	95	101	105	108	97	
6	75	Pumicite 25	2-1/4	0.77	5.7-7.4	16,130	100	90	99	102	98	98	
7	50	Slag 50	2-1/4	0.76	4.7-6.6	15,875	100	97	105	107	94	107	
8	65	Nat cem 35	2-1/4	0.76	5.7-6.4	15,625	100	98	106	108	98	107	
9	70	Cal sh 30	2-1/4	0.79	5.9-6.3	15,625	100	97	110	108	97	97	
10	88	Unc D 12	2-1/4	0.80	5.5-6.2	15,625	100	103	105	100	103	††	
10A	88	Unc D 12	2-1/4	0.80	5.5-6.2	16,130	100	100	105	98	98	105	
11	70	Fly ash 30	2-1/4	0.73	5.5-6.2	15,875	100	98	115	116	117	109	
11A	70	Fly ash 30	2-1/4	0.73	5.5-6.2	15,265	100	100	119	115	104	110	
12	100	0	3	0.55	6.3-7.4	16,395	100	97	104	105	98	103	
13	75	Pumicite 25	3	0.58	6.2-7.6	16,395	100	97	109	115	102	119	
14	50	Slag 50	3	0.60	5.8-6.3	16,395	100	100	117	111	91	117	
15	65	Nat cem 35	3	0.56	6.5-8.7	16,395	100	98	96	105	107	98	
16	75	Cal sh 25	3	0.59	5.7-7.4	16,130	100	98	98	105	102	105	
17	92	Unc D 8	3	0.55	5.3-7.4	16,395	100	98	105	111	109	112	
18	70	Fly ash 30	3	0.55	6.1-7.7	16,665	100	97	97	97	97	96	

(Continued)

Note: Nat cem = natural cement; cal sh = calcined shale; unc D = uncalcined diatomite; slag = blast-furnace slag.  
 \* Ratio of water to cementitious material based on total weight.

\*\* Air content of that portion of the concrete containing aggregate smaller than 1-1/2 in. in size.  
 † End of specimen too rough to obtain satisfactory reading.

†† The Resident Inspector did not clean this cube specimen in 1963, and as a result proper pulse velocity readings could not be taken. The cube was left uncleaned so that the Chief, Concrete Division, and other members of the November 1963 inspection party could observe how much seaweed would accumulate on a test specimen if it were not cleaned during the summer.

(Sheet 1)

(Revised Sept 1970)

Table 2-CRMI-PD (Continued)

Section 8

Cube No.	Cementitious Mat'l		Nominal Cement Factor bags/cu yd	Water-Cement Ratio by Wt	Air Content %	1964- Readings Beach Row 1 (W to E)					
	Type II Portland Cement %	Replace-ment Material %				692 Cycles 1964 $\bar{V}^2$	855 Cycles 1965 $\bar{V}^2$	985 Cycles 1966 $\bar{V}^2$	1141 Cycles 1967 $\bar{V}^2$	1326 Cycles 1968 $\bar{V}^2$	1480 Cycles 1969 $\bar{V}^2$
1	100	0	1-3/4	0.93	6.1-6.6	†	Failed				
2	65	Nat cem 35	1-3/4	0.96	1.7-8.2	35	†	†	Failed		
3	70	Cal sh 30	1-3/4	1.01	5.3-5.8	74	†		Failed		
4	88	Unc D 12	1-3/4	0.98	5.4-6.4	87	41		†	Failed	
5	100	0	2-1/4	0.73	3.9-6.1	91	105		91	78	65
6	75	Pumicite 25	2-1/4	0.77	5.7-7.4	92	110		†	†	Failed
7	50	Slag 50	2-1/4	0.76	4.7-6.6	78	110		83	86	†
8	65	Nat cem 35	2-1/4	0.76	5.7-6.4	103	103		82	62	†
9	70	Cal sh 30	2-1/4	0.79	5.9-6.3	103	114		82	85	†
10	88	Unc D 12	2-1/4	0.80	5.5-6.2	86	110		81	95	†
10A	88	Unc D 12	2-1/4	0.80	5.5-6.2	88	103		49	47	†
11	70	Fly ash 30	2-1/4	0.73	5.5-6.2	107	110		112	97	79
11A	70	Fly ash 30	2-1/4	0.73	5.5-6.2	98	105		97	90	†
12	100	0	3	0.55	6.3-7.4	101	103		78	78	57
13	75	Pumicite 25	3	0.58	6.2-7.6	121	123		113	100	103
14	50	Slag 50	3	0.60	5.8-6.3	107	103		109	107	105
15	65	Nat cem 35	3	0.56	6.5-8.7	94	105		97	107	86
16	75	Cal sh 25	3	0.59	5.7-7.4	97	112		102	105	95
17	92	Unc D 8	3	0.55	5.3-7.4	113	123		121	103	102
18	70	Fly ash 30	3	0.55	6.1-7.7	101	103		100	94	88

† End of specimen too rough to obtain satisfactory reading.

\* Satisfactory pulse velocity readings were not obtained in 1966 due to malfunction of testing equipment.

(Sheet 2)

(Revised August 1977)

Table 2-CRMI-PD (Continued)

Section 8

Cube No.	Cementitious Mat'l		Nominal Cement Factor bags/ cu yd	Water- Cement Ratio by Wt	Air Content %	1970-1976 Readings							Beach Row 1 (W to E)	
	Type II Portland Cement %	Replace- ment Material %				1633 Cycles 1970 %V <sup>2</sup>	1802 Cycles 1971 %V <sup>2</sup>	1959 Cycles 1972 %V <sup>2</sup>	2099 Cycles 1973 %V <sup>2</sup>	2238 Cycles 1974 %V <sup>2</sup>	2350 Cycles 1975 %V <sup>2</sup>	2496 Cycles 1976 %V <sup>2</sup>		
5	100	0	2-1/4	0.73	3.9-6.1	Failed								
7	50	Slag 50	2-1/4	0.76	4.7-6.6	Failed								
8	65	Nat cem 35	2-1/4	0.76	5.7-6.4	Failed								
9	70	Cal sh 30	2-1/4	0.79	5.9-6.3	Failed								
10	88	Unc D 12	2-1/4	0.80	5.5-6.2	†	Failed							
10A	88	Unc D 12	2-1/4	0.80	5.5-6.2	†	Failed							
11	70	Fly ash 30	2-1/4	0.73	5.5-6.2	74	71	60	††	83	51	Failed		
11A	70	Fly ash 30	2-1/4	0.73	5.5-6.2	Failed								
12	100	0	3	0.55	6.3-7.4	†	Failed							
13	75	Pumicite 25	3	0.58	6.2-7.6	94	15	NR	††	Failed				
14	50	Slag 50	3	0.60	5.8-6.3	100	82	66	††	65	38	31		
15	65	Nat cem 35	3	0.56	6.5-8.7	82	48	49	††	44	NR	NR		
16	75	Cal sh 25	3	0.59	5.7-7.4	91	NR	91	††	Failed				
17	92	Unc D 8	3	0.55	5.3-7.4	98	85	77	††	71	NR	NR		
18	70	Fly ash 30	3	0.55	6.1-7.7	85	15	Failed						

† End of specimen too rough to obtain satisfactory reading.  
 †† Equipment malfunctioned in 1973.

(Issued August 1977)

Table 2-CRMI-PD (Continued)

Section 8

Cube No.	Cementitious Mat'l		Nominal Cement Factor bags/ cu yd	Water- Cement Ratio by Wt	Air Content %	1977- Readings	
	Type II Portland Cement %	Replace- ment Material %				2573 Cycles 1977 FV <sup>2</sup>	Beach Row 1 (W to E)
5	100	0	2-1/4	0.73	3.9-6.1		
7	50	Slag 50	2-1/4	0.76	4.7-6.6		
8	65	Nat cem 35	2-1/4	0.76	5.7-6.4		
9	70	Cal sh 30	2-1/4	0.79	5.9-6.3		
10	88	Unc D 12	2-1/4	0.80	5.5-6.2		
10A	88	Unc D 12	2-1/4	0.80	5.5-6.2		
11	70	Fly ash 30	2-1/4	0.73	5.5-6.2		
11A	70	Fly ash 30	2-1/4	0.73	5.5-6.2		
12	100	0	3	0.55	6.3-7.4		
13	75	Pumicite 25	3	0.58	6.2-7.6		
14	50	Slag 50	3	0.60	5.8-6.3	Failed	
15	65	Nat cem 35	3	0.56	6.5-8.7	Failed	
16	75	Cal sh 25	3	0.59	5.7-7.4		
17	92	Unc D 8	3	0.55	5.3-7.4	89	
18	70	Fly ash 30	3	0.55	6.1-7.7		

(Corrected Aug 1965)

Section 9

Passamaquoddy Tidal Power Project\*

In connection with studies for the Passamaquoddy Tidal Power Project, 43 concrete columns\*\* (5 by 5 by 60 in.) were installed on the exposure rack at Treat Island in 1936. The purpose of the installation was to find the cement and aggregate combination that would give the greatest assurance of durability for the proposed concrete structures. The mixture data for these 43 specimens were as follows:

Spec No.	Cement	Cement Factor bags/cu yd	Coarse Aggregate	Sand- aggregate Ratio %	Water
B-14	Type I	5.25	Natural gravel A	34	Tap
B-19	Type I	5.25	Natural gravel A	30	Tap
B-26	Type I	5.25	Natural gravel A	28	Tap
B-31	Type I	5.25	Crushed diabase rock B	30	Tap
B-36	Type I	5.25	Crushed diabase rock C	34	Tap
B-39	Type I, 50%; other PC, 50%*	5.25	Crushed diabase rock C	34	Tap
B-46	Natural, 21%; Type I, 79%	5.25	Crushed diabase rock C	34	Tap
B-51	Type I	5.25	Crushed diabase rock B	32	Tap
B-56	Type I	5.25	Crushed diabase rock B	34	Tap
B-61	Type I	5.25	Crushed diabase rock B	36	Tap
B-66	Type I	5.25	Crushed diabase rock B	38	Tap
B-71	Aluminous cement	5.25	Crushed diabase rock C	34	Tap
B-76	Pozzolan, 15%; Type I, 85%	5.25	Crushed diabase rock C	34	Tap
B-81	Portland, pozzolan	5.25	Crushed diabase rock C	34	Tap
B-86	Type I	5.25	Crushed diabase rock C	34	Tap
B-88**	Type I	5.64	Crushed diabase rock B	40	Tap
D-1	Type I	5.25	Crushed diabase rock B	38	Tap
D-2	Type I	5.25	Crushed diabase rock B	36	Tap
D-3	Type I	5.50	Crushed diabase rock B	38	Tap
D-4	Type I	5.50	Crushed diabase rock C	36	Tap
D-5	Type I	5.50	Crushed diabase rock C	38	Tap
D-6	Type I	5.50	Crushed diabase rock C	34	Tap
D-7	Type I	5.25	Crushed diabase rock C	36	Tap
D-8	Type I	5.50	Crushed diabase rock C	40	Tap
D-9	Type I	5.25	Crushed diabase rock C	38	Tap
S-3-R†	Type I	5.00	Natural gravel A	32	Tap
S-5	Aluminous cement	5.00	Natural gravel A	32	Tap
S-7	Type I	5.00	Natural gravel A	32	Sea (conc)
S-2	Type I	5.00	Natural gravel A	32	Tap
S-4-R†	Aluminous cement	5.00	Natural gravel A	32	Tap
S-8-R†	Type I	5.00	Natural gravel A	32	Sea (conc)
S-10	Portland, pozzolan	5.00	Natural gravel A	32	Tap
S-11-R†	Portland, pozzolan	5.00	Natural gravel A	32	Tap
S-13-R†	Aluminous cement	5.00	Natural gravel A	32	Sea (normal)
S-14	Aluminous cement	5.00	Natural gravel A	32	Sea (normal)
S-16	Portland, pozzolan	5.00	Natural gravel A	32	Sea (conc)
S-17-R†	Portland, pozzolan	5.00	Natural gravel A	32	Sea (conc)
S-20-R†	Type I	5.00	Natural gravel A	32	Sea (normal)
S-21	Type I	5.00	Natural gravel A	32	Sea (normal)
S-22	Aluminous cement	5.00	Natural gravel A	32	Sea (conc)
S-23-R†	Aluminous cement	5.00	Natural gravel A	32	Sea (conc)
S-25	Portland, pozzolan	5.00	Natural gravel A	32	Sea (normal)
S-26-R†	Portland, pozzolan	5.00	Natural gravel A	32	Sea (normal)

Note: Maximum size aggregate, 2 in.; fine aggregate, natural sand (A); 5- by 5- by 60-in. columns; water-cement ratio, 6 gal per bag.

\* This cement does not meet all of the present specifications for any of the types of portland cement.

\*\* Fine aggregate was manufactured sand (B).

† Specimen contains 3/4-in. reinforcing bar.

\* See Passamaquoddy Tidal Power Development, Final Report of Concrete Tests (15 September 1936).

\*\* Columns are molded with the long axis in a vertical position.

In October 1940, after approximately 600 cycles of freezing-and-thawing, the exposure of all but six specimens was discontinued. These six specimens were selected as the most durable, and were reinstalled on the exposure rack.

Three of the six specimens (B-14, B-39, and B-86) contained plain portland cement which was manufactured by a mill which permitted the introduction of crusher oil into the cement (thereby possibly introducing involuntary air-entrainment). These three columns contained concrete having a cement factor of 5.25 bags per cu yd, and a water-cement ratio of 6.0 gal per bag. The other three columns (S-4-R, S-13-R, and S-23-R), each containing one 3/4-in.-diameter, deformed, reinforcing steel bar, were made with aluminous cement (cement factor = 5.0 bags per cu yd, water-cement ratio = 6.0 gal per bag). The aggregate used in all six columns was a granitic sand and gravel (2-in. maximum size) from an esker.

Table 1-PQ gives the exposure record of these six specimens.

(Revised Sept 1969)

Table 1-PQ

Section 9

Record of Observations of Concrete Columns Containing Cement-Aggregate Combinations Proposed for  
Passamaquoddy Tidal Power Project Structures

1936- (Installed in 1936)

1936-1941 Observations												
Speci- men	Type Cement	Type Water	1936		1937		1938		1940		1941	
			Cycles	Condi- tion	* Cycles	Condi- tion	Cycles	Condi- tion	Cycles	Condi- tion	Cycles	Condi- tion
<u>Specimens Without Reinforcing Bar</u>												
B-14	Type I	Tap	0	Sound	422	Vy good	598	Vy good	759	Vy good	916	Good
B-39	Type I, 50%; other PC, 50%**	Tap	0	Sound	378	Vy good	554	Vy good	715	Vy good	872	Good
B-86	Type I	Tap	0	Sound	361	Excel.	537	Vy good	698	Vy good	855	Vy good
<u>Specimens with Reinforcing Bar</u>												
S-4-R	Aluminous	Tap	0	Sound	288	Excel.	464	Excel.	625	Good	782	Good
S-13-R	Aluminous	Sea (normal)	0	Sound	288	Vy good	464	Good	625	Good	782	Good
S-23-R	Aluminous	Sea (conc)	0	Sound	288	Vy good	464	Good	625	Good	782	Good

			1942-1958 Observations									
			1942		1943		1948		1957		1958	
			Cycles	Condi- tion	Cycles	Condi- tion	Cycles	Condi- tion	Cycles	Condi- tion	Cycles	Condi- tion
<u>Specimens Without Reinforcing Bar</u>												
B-14	Type I	Tap	1082	Fair	1270	Failed						
B-39	Type I, 50%; other PC, 50%**	Tap	1038	Fair	1226	Failed						
B-86	Type I	Tap	1021	Good	1209	Failed						
<u>Specimens with Reinforcing Bar</u>												
S-4-R	Aluminous	Tap	948	Fair	1136	Fair	1742	Fair	2850	Poor	2921	Poor
S-13-R	Aluminous	Sea (normal)	948	Good	1136	Good	1742	Fair	2850	Fair	2921	Fair
S-23-R	Aluminous	Sea (conc)	948	Good	1136	Good	1742	Poor	2850	Failed		

Exposure Rack, Row 2, West End												
1959-1963 Observations												
			1959		1960		1961		1962		1963	
			Cycles	Condi- tion	Cycles	Condi- tion	Cycles	Condi- tion	Cycles	Condi- tion	Cycles	Condi- tion
<u>Specimens with Reinforcing Bar</u>												
S-4-R	Aluminous	Tap	3071	Poor	3142	Poor	3283	Poor	3372	Failed		
S-13-R	Aluminous	Sea (normal)	3071	Fair	3142	Fair	3283	Fair	3372	Fair	3478	Fair

			Exposure Rack, Row 8, West End									
			1964-1968 Observations									
			1964		1965		1966		1967		1968	
			Cycles	Condi- tion	Cycles	Condi- tion	Cycles	Condi- tion	Cycles	Condi- tion	Cycles	Condi- tion
<u>Specimens with Reinforcing Bar</u>												
S-13-R	Aluminous	Sea (normal)	3613	Fair	3776	Fair	3906	Fair	4062	Fair	4247	Fair

(Continued)

\* Specimens were installed on different dates in 1936; hence different numbers of freezing-and-thawing cycles.  
 \*\* This cement does not meet all of the present specifications for any of the types of portland cement.

(Sheet 1)

(Revised August 1977)

Table 1-PQ (Continued)

Section 9

Exposure Rack, Row 8, West End													
Speci- men	Type Cement	Type Water	1969-1973 Observations										
			1969		1970		1971		1972		1973		
			Condi- tion	Cycles	Condi- tion	Cycles	Condi- tion	Cycles	Condi- tion	Cycles	Condi- tion		
			Cycles	Condi- tion	Cycles	Condi- tion	Cycles	Condi- tion	Cycles	Condi- tion	Cycles	Condi- tion	
Specimens with Reinforcing Bar													
S-13-R	Aluminous	Sea (normal)	4401	Fair	4554	Fair	4723	Fair	4880	Fair	5020	Fair	
1974- Observations													
			1974		1975		1976		1977				
			Condi- tion	Cycles	Condi- tion	Cycles	Condi- tion	Cycles	Condi- tion	Cycles			Condi- tion
			Cycles	Condi- tion	Cycles	Condi- tion	Cycles	Condi- tion	Cycles	Condi- tion			
S-13-R	Aluminous	Sea (normal)	5159	Fair	5271	Fair*	5417	Fair	5494	Fair			

\* Approximately 6 in. saved off one end in 1975 for laboratory tests by PCA.

Missouri River Division Program1963 installation

In September 1963, 12 sawed mortar beams (3-1/2 by 4-1/2 by 16 in.) were installed on the Treat Island exposure rack to provide field durability data on specimens from various projects in the Missouri River Division.

This installation was made up of five series of beams; the specimens\* represented five different mortar mixtures and were sawed from 3-ft-square by nominally 3-1/2-in.-thick test panels. The mortar was placed pneumatically (shot) in each of the panels at each jobsite.

Table 1-SC lists the specimens and gives their exposure record along with other pertinent data.

Companion specimens (3-1/2 by 4-1/2 by 16 in.) to the Treat Island exposure specimens were subjected to laboratory freezing-and-thawing tests in the Missouri River Division Laboratory, Omaha, Nebr. The companion beams were also sawed from the test panels. The results of the laboratory tests are given below:

<u>Mixture No.</u>	<u>No. of Beams Tested</u>	<u>Age at Test days</u>	<u>Avg %E at 300 Cycles of Freezing-and- Thawing</u>
1	3	14	78
2	3	14	29
3	3	90	14
4	3	90	6
5	3	21	3

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\* Four of the beams contained mesh reinforcing.

(Issued Sept 1966)

Section 10

1965 installation

In November 1965, three sawed concrete beams (3 by 4-1/2 by 16 in.) were installed on the Treat Island exposure rack to provide field durability data on specimens from a specific project in the Missouri River Division.

The specimens represented one concrete mixture and were sawed from a 3-ft-square by 3-in.-thick test slab. The test slab was placed pneumatically (shot) as a reinforcement to rock slope bank protection.

Table 2-SC lists the specimens and gives their exposure record along with other pertinent data.

(Revised May 1976)

Table 1-SC

Section 10

Record of Testing of Mortar Beams, Missouri River Division Program  
1963 - (Installed September 1963)

Beam No.	Mixture No.	Cement/ Aggregate Ratio as Shot (by wt)	Position of Panel When Shot	Type Cement	Fine Aggregate	Reinforcing Mesh	Exposure Rack, Row 5 (W to E)			
							0 Cycles 1963 %E	135 Cycles 1964 %E	298 Cycles 1965 %E	428 Cycles 1966 %E
1A	1	1:3.5	Vertical	II, A	Sand A	Yes	100	99	101	100
1B	1	1:3.5	Vertical	II, A	Sand A	Yes	100	99	99	100
2A	2	1:4.0	Vertical	II, A	Sand A	No	100	119	120	127
2B	2	1:4.0	Vertical	II, A	Sand A	No	100	92	89	97
2C	2	1:4.0	Vertical	II, A	Sand A	Yes	100	122	124	126
2D	2	1:4.0	Vertical	II, A	Sand A	Yes	100	99	101	116
3A	3	1:3.8	Horizontal	II, B	Sand B	No	100	125	124	125
3B	3	1:3.8	Horizontal	II, B	Sand B	No	100	125	125	127
4A	4	1:3.8	Vertical	II, B	Sand B	No	100	73	74	93
4B	4	1:3.8	Vertical	II, B	Sand B	No	100	101	105	112
5A	5	1:3.5	Vertical	I, C	Sand C	No	100	101	102	105
5B	5	1:3.5	Vertical	I, C	Sand C	No	100	101	102	101
							584 Cycles 1967 %E	769 Cycles 1968 %E	923 Cycles 1969 %E	1076 Cycles 1970 %E
1A	1	1:3.5	Vertical	II, A	Sand A	Yes	100	99	100	100
1B	1	1:3.5	Vertical	II, A	Sand A	Yes	102	102	100	104
2A	2	1:4.0	Vertical	II, A	Sand A	No	125	125	127	136
2B	2	1:4.0	Vertical	II, A	Sand A	No	97	Broken in handling		
2C	2	1:4.0	Vertical	II, A	Sand A	Yes	123	123	125	133
2D	2	1:4.0	Vertical	II, A	Sand A	Yes	121	123	126	133
3A	3	1:3.8	Horizontal	II, B	Sand B	No	125	134	136	143
3B	3	1:3.8	Horizontal	II, B	Sand B	No	127	129	129	143
4A	4	1:3.8	Vertical	II, B	Sand B	No	91	62	65	68
4B	4	1:3.8	Vertical	II, B	Sand B	No	110	114	110	NR
5A	5	1:3.5	Vertical	I, C	Sand C	No	103	102	105	NR
5B	5	1:3.5	Vertical	I, C	Sand C	No	101	83	81	NR
							1245 Cycles 1971 %E	1402 Cycles 1972 %E	1542 Cycles 1973 %E	1681 Cycles 1974 %E
1A	1	1:3.5	Vertical	II, A	Sand A	Yes	97	96	95	96
1B	1	1:3.5	Vertical	II, A	Sand A	Yes	103	102	94	104
2A	2	1:4.0	Vertical	II, A	Sand A	No	129	141	116	123
2C	2	1:4.0	Vertical	II, A	Sand A	Yes	128	110	96	105
2D	2	1:4.0	Vertical	II, A	Sand A	Yes	91	88	81	77
3A	3	1:3.8	Horizontal	II, B	Sand B	No	130	NR	Failed	
3B	3	1:3.8	Horizontal	II, B	Sand B	No	124	NR	Failed	
4A	4	1:3.8	Vertical	II, B	Sand B	No	63	NR	Failed	
4B	4	1:3.8	Vertical	II, B	Sand B	No	NR	NR	Failed	
5A	5	1:3.5	Vertical	I, C	Sand C	No	NR	NR	Failed	
5B	5	1:3.5	Vertical	I, C	Sand C	No	NR	NR	Failed	

NR A satisfactory reading was not obtained although an attempt was made to obtain one.

(Sheet 1)

(Revised August 1977)

Table 1-SC (Continued)

Section 10

Beam No.	Mixture No.	Cement/ Aggregate Ratio as Shot (by wt)	Position of Panel When Shot	Type Cement	Fine Aggregate	Reinforcing Mesh	Exposure Rack, Row 5 (W to E) Readings		
							1793 Cycles 1975	1939 Cycles 1976	1975- 2016 Cycles 1977
							%E	%E	%E
1A	1	1:3.5	Vertical	II, A	Sand A	Yes	96	101	102
1B	1	1:3.5	Vertical	II, A	Sand A	Yes	104	Failed	
2A	2	1:4.0	Vertical	II, A	Sand A	No	123	128	91
2C	2	1:4.0	Vertical	II, A	Sand A	Yes	105	121	107
2D	2	1:4.0	Vertical	II, A	Sand A	Yes	78	81	NR*
3A	3	1:3.8	Horizontal	II, B	Sand B	No			
3B	3	1:3.8	Horizontal	II, B	Sand B	No			
4A	4	1:3.8	Vertical	II, B	Sand B	No			
4B	4	1:3.8	Vertical	II, B	Sand B	No			
5A	5	1:3.5	Vertical	I, C	Sand C	No			
5B	5	1:3.5	Vertical	I, C	Sand C	No			

\* NR denotes a satisfactory reading could not be obtained.

(Revised August 1977)

Table 2-SC

Section 10

Record of Testing of Concrete Beams, Missouri River Division Program

1965- (Installed November 1965)

							Exposure Rack, Row 5 (W to E)							
							1965-1972 Readings							
Beam No.	Mixture No.	Type Cement	Fine Aggregate	Coarse Aggregate	Air Content %		0	130	286	471	625	778	947	1104
							Cycles 1965	Cycles 1966	Cycles 1967	Cycles 1968	Cycles 1969	Cycles 1970	Cycles 1971	Cycles 1972
							%E	%E	%E	%E	%E	%E	%E	%E
SC-1	6	I, D	Sand D	Gravel A	7.5		100	92	94	100	100	101	96	65
SC-2	6	I, D	Sand D	Gravel A	7.5		100	97	99	96	94	91	73	49
SC-3	6	I, D	Sand D	Gravel A	7.5		100	102	102	100	102	102	80	65
							1973- Readings							
							1244	1383	1495	1641	1718			
							Cycles 1973	Cycles 1974	Cycles 1975	Cycles 1976	Cycles 1977			
							%E	%E	%E	%E	%E			
SC-1	6	I, D	Sand D	Gravel A	7.5		89	81	80	82	NR			
SC-2	6	I, D	Sand D	Gravel A	7.5		NR	Failed						
SC-3	6	I, D	Sand D	Gravel A	7.5		45	NR	NR	NR	NR			

NR denotes no reading was obtained even though an attempt was made to obtain one.

Portland Blast-Furnace Slag Cement Investigation\*

This investigation was initiated in FY 1955 to evaluate the performance of blast-furnace slag cement and determine how its performance compares with that of type II portland cement. Twelve air-entrained concrete mixtures were used in the investigation, the difference between the mixtures being the type cement used. Eight portland blast-furnace slag cements, one type II portland cement, and three blends of portland blast-furnace slag cement and natural cement were used. The aggregates used were limestone (3/4-in. maximum size) and natural sand. The cement factor was 5.5 bags per cu yd for all mixtures, and the air content was  $6.0 \pm 0.5$  percent.

Eighteen beams (3-1/2 by 4-1/2 by 16 in.) were fabricated from each of the 12 concrete mixtures (total of 216 beams). Half of these beams (108) were installed on the exposure rack at Treat Island in May 1956; the other half (108) were installed on the St. Augustine exposure rack in August 1956.

Table 1-BFS lists the specimens exposed at Treat Island and gives their exposure record along with their cements.

Table 2-BFS lists the specimens exposed at St. Augustine, and gives their exposure record along with their cements.

In 1956 the question of whether reinforcing steel surrounded by portland blast-furnace slag cement concrete was more prone to corrosion than that surrounded by portland-cement concrete was raised. To answer this question, 45 concrete prisms (8-1/2 by 8-1/2 by 12 in.), each containing 4 pieces of reinforcing bars, were fabricated and installed on the exposure rack at St. Augustine in August 1956. The aggregates and concrete mixtures were the same as those used to fabricate the beams described above except that only three cements were used: two

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\* See U. S. Army Engineer Waterways Experiment Station, CE, Investigation of Portland Blast-Furnace Slag Cements, Technical Report No. 6-445, also U. S. Army Engineer Waterways Experiment Station, CE, Investigation of Portland Blast-Furnace Slag Cements; Supplementary Data, by Bryant Mather, Technical Report No. 6-445, Report No. 2 (Vicksburg, Miss., September 1965).

## Section 11

(Revised Jan 1972)

blast-furnace slag cements and one type II portland cement. No tests of these prisms were scheduled while they were undergoing field exposure. They were to be returned to the laboratory for examination in accordance with the following schedule:

Cement	No. of Prisms Installed	No. of Prisms to be Re- turned to Laboratory in:		
		1958	1960	1961
Type II, portland cement	15	6	6	3
PBFS* No. 1	15	6	6	3
PBFS* No. 2	15	6	6	3

\* Portland blast-furnace slag cement.

Specimens examined after two, four, and five years exposure showed the same relative relation of cement type to amount of corrosion of embedded steel, with the amount of rusting increasing with length of exposure. A "pinpoint" of rust was considered as 1 unit area of corrosion; spots 1/16 in. in diameter were regarded as 4 units; those 1/8 in. in diameter as 16 units, etc. Total average rusted area on all bars, per specimen, arranged by cements was as follows:

Average Rusted Area on Bars, by Cement			Length of Exposure years	Date
Type II	PBFS No. 1	PBFS No. 2		
173	17	79	2	1958
1877	60	258	4	1960
2827	111	427	5	1961

Testing of specimens exposed at St. Augustine exposure station was discontinued after the 1970 inspection.

(Revised Sept 1967)

Table 1-BFS

Section 11

## Record of Testing of Concrete Beams Made for Portland Blast-furnace Slag Cement Investigation, Exposed at Treat Island

1956- (Installed May 1956)

Beam No.	Cement	Exposure Rack, Row 5 (W to E)											
		1956-1967 Readings											
		0 Cycles 1956 \$E	144 Cycles 1957 \$E	215 Cycles 1958 \$E	365 Cycles 1959 \$E	436 Cycles 1960 \$E	577 Cycles 1961 \$E	666 Cycles 1962 \$E	772 Cycles 1963 \$E	907 Cycles 1964 \$E	1070 Cycles 1965 \$E	1200 Cycles 1966 \$E	1356 Cycles 1967 \$E
1ST-2	PBFS* No. 3	100	109	117	115	**							
1ST-4		100	111	117	116	114	109	112	112	110	110	110	108
1ST-6		100	111	119	116	115	110	122	116	117	120	119	115
1ST-8		100	117	123	125	121	117	118	118	114	114	114	114
1ST-10		100	116	121	122	122	115	115	112	111	110	109	108
1ST-12		100	116	125	126	125	118	116	116	113	113	113	112
1ST-14		100	108	115	119	117	112	111	114	112	111	112	112
1ST-16		100	108	115	118	117	109	110	110	107	109	111	110
1ST-18		100	109	117	119	118	112	113	114	111	111	109	109
2ST-20	PBFS No. 4	100	118	125	128	125	119	121	122	117	118	119	118
2ST-22		100	121	130	129	125	118	122	123	119	119	119	119
2ST-24		100	120	128	133	128	122	126	124	120	120	122	120
2ST-26		100	123	134	135	**							
2ST-28		100	123	134	134	133	123	128	126	126	125	124	123
2ST-30		100	122	133	134	131	122	127	127	125	124	124	124
2ST-32		100	122	132	134	132	127	129	129	128	127	125	123
2ST-34		100	121	130	131	130	125	124	126	122	122	124	124
2ST-36		100	120	136	130	126	121	123	122	122	120	121	120
3ST-38	PBFS No. 1	100	119	128	130	141	122	124	123	127	126	128	126
3ST-40		100	113	123	124	**							
3ST-42		100	118	128	130	128	122	127	126	122	122	122	122
3ST-44		100	128	138	139	138	130	129	128	119	114	112	112
3ST-46		100	122	128	132	131	122	123	122	115	114	112	110
3ST-48		100	122	128	132	131	122	122	123	121	120	119	115
3ST-50		100	124	131	135	134	125	127	128	128	120	120	119
3ST-52		100	123	130	134	133	124	126	126	125	121	119	119
3ST-54		100	123	132	134	132	124	125	125	125	123	123	121
4ST-56	PBFS No. 2	100	119	128	131	128	121	123	124	128	125	125	125
4ST-58		100	118	126	128	**							
4ST-60		100	114	123	124	124	117	123	121	127	128	128	125
4ST-62		100	125	130	136	133	126	128	127	126	126	122	121
4ST-64		100	126	135	136	135	126	131	130	130	125	121	120
4ST-66		100	127	134	135	134	124	128	127	126	123	123	123
4ST-68		100	118	125	130	128	121	123	125	123	121	120	119
4ST-70		100	117	125	129	128	121	122	121	121	121	120	120
4ST-72		100	120	127	132	130	123	124	126	126	120	120	120
5ST-74	PBFS No. 5	100	105	112	114	112	106	110	110	110	110	108	108
5ST-76		100	106	113	113	112	105	110	107	104	105	105	104
5ST-78		100	110	116	117	116	109	111	111	109	109	110	109
5ST-80		100	116	123	122	**							
5ST-82		100	117	125	124	123	115	116	114	114	114	115	116
5ST-84		100	120	124	124	122	114	117	113	113	112	111	111
5ST-86		100	115	122	124	122	115	116	114	113	115	113	111
5ST-88		100	112	118	121	119	112	113	112	110	112	112	112
5ST-90		100	114	122	123	120	112	115	114	108	108	108	106
6ST-92	PBFS No. 6	100	121	129	131	130	121	125	123	118	120	118	118
6ST-94		100	124	132	135	**							
6ST-96		100	123	133	134	134	124	128	128	127	127	127	124
6ST-98		100	125	134	134	133	125	124	120	119	117	122	122
6ST-100		100	124	135	137	132	124	124	125	116	117	121	119
6ST-102		100	124	133	136	136	127	127	128	123	121	126	125
6ST-104		100	120	130	130	128	121	121	121	117	116	119	119
6ST-106		100	126	135	134	134	125	125	124	120	119	119	117
6ST-108		100	123	129	131	129	120	120	120	117	115	117	118
7ST-110	PBFS No. 7	100	114	124	126	**							
7ST-112		100	116	124	126	125	118	117	121	120	118	118	117
7ST-114		100	115	124	124	124	120	121	120	116	116	118	117
7ST-116		100	121	129	131	131	122	123	125	123	121	123	121
7ST-118		100	122	130	133	130	124	127	126	125	125	123	123
7ST-120		100	121	131	134	134	123	125	126	125	121	122	121
7ST-122		100	117	126	128	126	118	121	120	120	116	118	117
7ST-124		100	115	122	126	125	117	119	118	116	114	115	115
7ST-126		100	114	123	127	125	118	119	120	115	113	115	115

(Continued)

Note: From 1956 to 1958 the wooden tie-downs were resting directly on these specimens; thereafter they were spaced so as not to touch the concrete.

\* Portland blast-furnace slag cement.

\*\* Returned to laboratory 1959.

(Sheet 1)

(Revised August 1977)

Table 1-BFS (Continued)

Section 11

Beam No.	Cement	1956-1967 Readings											Exposure Rack, Row 5 (W to E)	
		0	144	215	365	436	577	666	772	907	1070	1200	1356	
		Cycles 1956 %E	Cycles 1957 %E	Cycles 1958 %E	Cycles 1959 %E	Cycles 1960 %E	Cycles 1961 %E	Cycles 1962 %E	Cycles 1963 %E	Cycles 1964 %E	Cycles 1965 %E	Cycles 1966 %E	Cycles 1967 %E	
8ST-128	Type II PC†	100	121	128	130	125	120	120	121	121	118	121	120	
8ST-130		100	117	123	125	123	116	114	116	116	114	114	114	
8ST-132		100	120	126	126	122	115	114	112	108	108	110	110	
8ST-134		100	125	133	134	132	123	125	123	122	118	120	118	
8ST-136		100	123	132	132	**								
8ST-138		100	123	129	133	128	120	122	121	115	115	117	115	
8ST-140		100	123	130	132	128	120	120	122	120	120	120	119	
8ST-142		100	123	130	131	129	119	121	123	118	116	116	116	
8ST-144		100	127	135	136	132	124	126	122	122	122	122	123	
9ST-146	PBFS* No. 8	100	112	120	120	120	110	115	116	112	112	111	111	
9ST-148		100	112	120	120	120	113	111	113	111	111	111	111	
9ST-150		100	112	121	122	121	114	116	116	113	113	115	115	
9ST-152		100	114	122	124	122	116	117	116	114	113	116	118	
9ST-154		100	113	123	123	123	114	116	117	114	114	114	115	
9ST-156		100	110	119	119	**								
9ST-158		100	111	117	118	117	107	108	106	103	105	103	104	
9ST-160		100	109	116	117	118	110	111	109	107	103	105	105	
9ST-162		100	111	118	120	119	110	110	108	106	102	106	106	
10ST-164	Blend: No. 2 PBFS, 80%; nat cem A, 20%††	100	116	124	128	127	120	120	119	118	116	118	117	
10ST-166		100	115	120	123	120	113	115	116	109	109	109	110	
10ST-168		100	107	113	115	111	104	107	103	101	98	91	93	
10ST-170		100	114	121	123	**								
10ST-172		100	113	121	122	122	112	111	111	107	105	103	105	
10ST-174		100	110	117	120	117	108	110	108	105	103	100	99	
10ST-176		100	112	119	122	119	111	113	111	109	106	106	110	
10ST-178		100	111	118	120	118	110	110	111	110	108	106	108	
10ST-180		100	111	117	119	117	108	109	107	102	104	101	101	
11ST-182	Blend: No. 2 PBFS, 75%; nat cem A, 25%	100	109	115	115	113	104	108	102	97	94	92	93	
11ST-184		100	105	110	113	113	101	103	101	94	89	89	89	
11ST-186		100	108	114	116	114	102	105	103	96	94	92	92	
11ST-188		100	119	125	129	128	120	121	121	118	119	118	117	
11ST-190		100	111	118	120	**								
11ST-192		100	109	117	118	116	106	102	108	106	113	115	117	
11ST-194		100	110	118	117	116	104	106	103	95	72	78	77	
11ST-196		100	106	114	111	109	93	92	92	83	81	94	93	
11ST-198		100	106	113	115	112	101	103	101	95	92	90	90	
12ST-200	Blend: No. 2 PBFS, 70%; nat cem A, 30%	100	106	110	112	110	100	105	100	95	92	90	90	
12ST-202		100	101	109	109	105	83	95	94	92	89	80	81	
12ST-204		100	99	103	103	101	88	89	89	84	75	72	71	
12ST-206		100	100	104	100	100	84	87	78	74	70	62	60	
12ST-208		100	102	106	104	104	90	92	88	79	74	69	65	
12ST-210		100	111	117	116	116	103	107	103	100	95	97	97	
12ST-212		100	113	120	126	121	109	110	110	107	104	101	100	
12ST-214		100	117	123	126	124	114	118	118	111	106	104	107	
12ST-216		100	120	126	128	**								
1968- Readings														
		1541	1695	1848	2017	2174	2314	2453	2565	2711	2788			
		Cycles 1968 %E	Cycles 1969 %E	Cycles 1970 %E	Cycles 1971 %E	Cycles 1972 %E	Cycles 1973 %E	Cycles 1974 %E	Cycles 1975 %E	Cycles 1976 %E	Cycles 1977 %E			
1ST-4	PBFS No. 3	109	110	112	112	100	Failed							
1ST-6		120	117	120	121	105	Failed							
1ST-8		112	114	113	114	99	Failed							
1ST-10		113	114	110	103	103	97	98	148	116				
1ST-12		111	112	112	111	116	100	102	102	127	NR			
1ST-14		113	114	108	108	110	98	98	100	102	102			
1ST-16		106	102	102	102	121	75	79	79	NR	NR			
1ST-18		105	103	103	109	116	104	150	152	NR	NR			
2ST-20	PBFS No. 4	114	118	116	117	122	122	153	153	NR	NR			
2ST-22		117	121	119	121	123	154	154	160	NR	NR			
2ST-24		120	125	120	122	118	123	118	123	184	191			
2ST-28		125	123	119	124	123	109	98	100	147	NR			
2ST-30		123	125	118	123	127	110	117	118	122	141			
2ST-32		125	126	120	128	128	110	111	112	121	136			
2ST-34		119	120	114	118	116	123	124	128	134	135			
2ST-36		117	118	114	119	115	119	165	165	NR	NR			

\* Portland blast-furnace slag cement.

\*\* Returned to laboratory 1959.

† Portland cement.

†† Nat cem = natural cement.

NR A satisfactory reading was not obtained although an attempt was made to obtain one.

(Sheet 2)

(Revised August 1977)

Table 1-BFS (Continued)

Section 11

Beam No.	Cement	Exposure Rack, Row 5 (W to E)									
		1968- Readings									
		1541 Cycles 1968 %E	1695 Cycles 1969 %E	1848 Cycles 1970 %E	2017 Cycles 1971 %E	2174 Cycles 1972 %E	2314 Cycles 1973 %E	2453 Cycles 1974 %E	2565 Cycles 1975 %E	2711 Cycles 1976 %E	2788 Cycles 1977 %E
3ST-38	PBFS* No. 1	126	126	124	121	118	97	105	107	NR	NR
3ST-42		122	123	118	117	115	128	M			
3ST-44		103	102	94	NR	D					
3ST-46		99	98	97	NR	D					
3ST-48		115	116	NR	NR	D					
3ST-50		119	121	114	117	D					
3ST-52		117	118	111	114	D					
3ST-54		126	128	138	NR	D					
4ST-56	PBFS No. 2	125	126	125	128	116	NR	98	98	118	114
4ST-60		125	126	125	132	NR	NR	NR	NR	D	
4ST-62		113	116	106	113	NR	NR	M	M		
4ST-64		122	122	124	120	NR	NR	NR	NR	D	
4ST-66		120	123	115	116	NR	NR	M	M		
4ST-68		119	119	114	119	NR	NR	M	M		
4ST-70		121	119	110	114	107	140	137	142	136	124
4ST-72		120	120	113	118	NR	NR	M	M		
5ST-74	PBFS No. 5	106	110	114	111	104	105	107	107	NR	D
5ST-76		103	104	102	99	92	94	NR	NR	D	
5ST-78		109	107	107	103	97	100	97	99	133	137
5ST-82		111	111	112	107	104	104	M	M		
5ST-84		108	110	108	99	97	99	100	101	114	113
5ST-86		111	109	108	104	102	97	99	99	D	
5ST-88		110	110	107	105	102	96	88	90	96	96
5ST-90		103	102	102	96	95	70	77	78	100	106
6ST-92	PBFS No. 6	120	120	120	116	112	101	111	111	106	NR
6ST-96		126	124	125	120	115	114	114	115	NR	NR
6ST-98		120	121	115	110	107	113	113	114	D	
6ST-100		119	118	117	112	110	108	108	111	NR	D
6ST-102		125	124	124	120	116	117	117	117	NR	D
6ST-104		116	114	113	110	108	104	104	106	108	112
6ST-106		117	119	117	112	105	87	NR	NR	D	
6ST-108		117	115	113	106	92	92	93	95	91	NR
7ST-112	PBFS No. 7	118	117	117	109	106	105	103	105	103	NR
7ST-114		118	116	116	114	106	109	108	110	104	NR
7ST-116		122	121	119	114	114	109	107	112	110	NR
7ST-118		125	126	122	116	111	114	113	114	114	NR
7ST-120		122	118	118	114	107	109	107	112	115	118
7ST-122		114	114	109	100	100	97	96	98	98	NR
7ST-124		109	111	107	95	103	92	92	94	92	94
7ST-126		112	113	111	108	106	103	126	127	130	132
8ST-128	Type II PC†	118	116	114	114	123	123	118	120	118	119
8ST-130		114	112	110	116	105	114	114	116	105	115
8ST-132		108	110	108	109	99	107	107	111	112	117
8ST-134		120	119	118	113	105	123	121	122	122	124
8ST-138		117	115	115	111	104	119	116	118	114	117
8ST-140		119	121	119	107	104	114	132	130	131	121
8ST-142		116	114	116	112	109	111	119	117	118	119
8ST-144		121	120	118	114	111	111	118	118	142	146
9ST-146	PBFS No. 8	112	110	108	106	102	112	114	114	NR	D
9ST-148		113	111	111	109	105	116	119	118		
9ST-150		117	116	114	116	112	119	120	120		
9ST-152		116	114	114	114	123	118	174	160		
9ST-154		113	110	112	112	121	139	NR	NR		
9ST-158		101	100	100	100	115	83	NR	NR		
9ST-160		105	105	103	101	109	88	NR	NR		
9ST-162		106	104	105	107	116	104	105	105		
10ST-164	Blend: No. 2 PBFS, 80%; nat cem A, 20%††	114	116	114	106	NR	96	100	102		
10ST-166		102	100	98	108	109	93	96	96		
10ST-168		82	82	83	92	85	85	NR	NR		
10ST-172		101	101	101	74	D					
10ST-174		99	101	99	103	97	101	102	102		
10ST-176		106	104	102	103	96	76	91	89		
10ST-178		102	103	101	97	95	80	NR	NR		
10ST-180		93	91	91	Broken						

(Continued)

\* Portland blast-furnace slag cement.

† Portland cement.

†† Nat cem = natural cement.

NR A satisfactory reading was not obtained although an attempt was made to obtain one.

D Specimens so deteriorated that no reading can be obtained.

M Missing.

(Sheet 3)

(Revised August 1977)

Table 1-BFS (Continued)

Section 11

Beam No.	Cement	Exposure Rack, Row 5 (W to E)									
		1968-Readings								2711 Cycles	2788 Cycles
		1541 Cycles	1695 Cycles	1848 Cycles	2017 Cycles	2174 Cycles	2314 Cycles	2453 Cycles	2565 Cycles		
		1968 %E	1969 %E	1970 %E	1971 %E	1972 %E	1973 %E	1974 %E	1975 %E	1976 %E	1977 %E
11ST-182	Blend: No. 2	85	82	84	62	68	NR	NR	NR	D	D
11ST-184	PBFS, 75%;	80	76	81	52	56	NR	NR	NR		
11ST-186	nat cem A,	82	78	76	Broken						
11ST-188	25%	110	106	104	94	86	NR	NR	NR		
11ST-192		108	106	108	Broken						
11ST-194		69	64	66	Broken						
11ST-196		68	Failed								
11ST-198		86	82	75	66	62	NR	NR	NR		
12ST-200	Blend: No. 2	84	80	81	73	68	NR	NR	NR		
12ST-202	PBFS, * 70%;	Failed									
12ST-204	nat cem A,	Failed									
12ST-206	30%††	Failed									
12ST-208		Failed									
12ST-210		86	83	87	80	81	NR	NR	NR		
12ST-212		92	91	Failed							
12ST-214		95	93	96	Failed						

\* Portland blast-furnace slag cement.

†† Nat cem = natural cement.

NR A satisfactory reading was not obtained although an attempt was made to obtain one.

D Specimens so deteriorated that no reading can be obtained.

(Sheet 4)

(Revised Sept 1966)

Table 2-EFS

Section 11

## Record of Testing of Concrete Beams Made for Portland Blast-furnace Slag Cement Investigation, Exposed at St. Augustine

1956- (Installed August 1956)

Beam No.	Cement	1956-1966 Readings					
		1956 \$E	1958 \$E	1960 \$E	1962 \$E	1964 \$E	1966 \$E
1SA-1	PEFS* No. 3	100	113	118	116	118	125
1SA-3		100	112	119	118	120	118
1SA-5		100	115	127	119	121	129
1SA-7		100	116	128	116	123	122
1SA-9		100	116	130	119	121	120
1SA-11		100	118	131	120	122	122
1SA-13		100	107	118	107	109	109
1SA-15		100	107	117	108	110	108
1SA-17		100	107	118	109	110	111
2SA-19	PEFS No. 4	100	122	136	139	144	141
2SA-21		100	123	137	126	127	128
2SA-23		100	121	135	123	125	124
2SA-25		100	127	142	117	118	118
2SA-27		100	126	139	128	129	129
2SA-29		100	127	142	130	130	131
2SA-31		100	119	125	118	120	121
2SA-33		100	116	120	113	115	115
2SA-35		100	119	125	118	118	120
3SA-37	PEFS No. 1	100	123	137	125	130	130
3SA-39		100	123	134	125	127	127
3SA-41		100	125	138	128	131	132
3SA-43		100	129	142	139	142	142
3SA-45		100	131	147	136	139	139
3SA-47		100	130	142	139	142	142
3SA-49		100	126	147	119	120	119
3SA-51		100	123	136	117	103	117
3SA-53		100	123	136	114	93	116
4SA-55	PEFS No. 2	100	123	137	137	119	138
4SA-57		100	123	136	125	130	131
4SA-59		100	122	136	126	129	129
4SA-61		100	131	144	131	134	134
4SA-63		100	134	145	135	136	137
4SA-65		100	133	145	133	133	134
4SA-67		100	119	130	119	134	134
4SA-69		100	115	124	112	127	118
4SA-71		100	114	121	112	112	113
5SA-73	PEFS No. 5	100	117	126	117	131	116
5SA-75		100	117	129	116	118	117
5SA-77		100	118	129	117	118	118
5SA-79		100	114	123	114	116	111
5SA-81		100	115	127	114	117	116
5SA-83		100	115	127	115	115	115
5SA-85		100	113	123	113	115	114
5SA-87		100	114	123	116	118	118
5SA-89		100	115	128	113	116	115
6SA-91	PEFS No. 6	100	127	140	130	130	130
6SA-93		100	128	136	121	146	125
6SA-95		100	129	131	123	123	125
6SA-97		100	121	135	124	125	127
6SA-99		100	122	128	121	121	122
6SA-101		100	120	127	115	117	117
6SA-103		100	125	134	127	125	127
6SA-105		100	125	131	123	129	127
6SA-107		100	122	138	124	125	125
7SA-109	PEFS No. 7	100	122	130	121	121	121
7SA-111		100	122	128	116	118	118
7SA-113		100	123	128	119	117	126
7SA-115		100	131	143	131	132	128
7SA-117		100	131	140	130	127	128
7SA-119		100	130	140	128	129	129
7SA-121		100	122	130	118	119	119
7SA-123		100	121	129	120	120	118
7SA-125		100	120	128	116	118	125

(Continued)

(Revised Sept 1970)

Table 2-BFS (Continued)

Section 11

Beam No.	Cement	1956-1966 Readings					
		1956 %E	1958 %E	1960 %E	1962 %E	1964 %E	1966 %E
8SA-127	Type II PC**	100	126	134	121	126	121
8SA-129		100	126	136	124	122	124
8SA-131		100	126	134	122	121	121
8SA-133		100	125	132	120	120	123
8SA-135		100	125	132	120	120	121
8SA-137		100	125	136	122	122	115
8SA-139		100	128	135	120	120	122
8SA-141		100	131	137	125	125	132
8SA-143		100	129	135	120	120	132
9SA-145	PBFS* No. 8	100	121	130	116	116	114
9SA-147		100	119	128	117	117	113
9SA-149		100	119	128	117	117	111
9SA-151		100	117	124	112	112	110
9SA-153		100	115	124	115	117	117
9SA-155		100	114	116	107	107	109
9SA-157		100	120	129	117	117	119
9SA-159		100	122	130	117	119	121
9SA-161		100	120	129	117	119	118
10SA-163	Blend: No. 2 PBFS, 80%; nat cem A, 20%†	100	123	131	117	122	122
10SA-165		100	124	134	120	122	122
10SA-167		100	128	138	126	135	126
10SA-169		100	124	127	117	118	113
10SA-171		100	122	130	123	124	124
10SA-173		100	123	130	114	115	120
10SA-175		100	124	135	118	119	122
10SA-177		100	124	136	124	125	123
10SA-179		100	126	137	125	127	126
11SA-181	Blend: No. 2 PBFS, 75%; nat cem A, 25%	100	125	133	120	123	123
11SA-183		100	123	131	119	119	119
11SA-185		100	124	130	118	119	126
11SA-187		100	128	138	123	123	128
11SA-189		100	129	138	122	124	128
11SA-191		100	127	136	125	126	130
11SA-193		100	123	131	122	124	119
11SA-195		100	123	130	118	120	120
11SA-197		100	126	137	122	124	126
12SA-199	Blend: No. 2 PBFS, 70%; nat cem A, 30%	100	121	129	117	124	121
12SA-201		100	118	125	114	120	109
12SA-203		100	121	127	111	111	120
12SA-205		100	125	129	127	128	123
12SA-207		100	124	131	119	119	121
12SA-209		100	122	128	117	116	118
12SA-211		100	122	129	118	119	126
12SA-213		100	130	138	125	125	130
12SA-215		100	131	140	127	128	Lost
		1968- Readings					
		1968 %E	1970 %E				
1SA-1	PBFS No. 3	125	Lost				
1SA-3		118	117				
1SA-5		121	121				
1SA-7		123	121				
1SA-9		118	118				
1SA-11		120	119				
1SA-13		103	103				
1SA-15		107	107				
1SA-17		108	107				
2SA-19	PBFS No. 4	136	133				
2SA-21		124	122				
2SA-23		117	117				
2SA-25		112	112				
2SA-27		133	134				
2SA-29		135	135				
2SA-31		122	121				
2SA-33		115	113				
2SA-35		120	120				

\* Portland blast-furnace slag cement.

\*\* PC = portland cement.

† Nat cem = natural cement.

(Sheet 2)

(Revised Sept 1970)

Table 2-BFS (Continued)

Section 11

Beam No.	Cement	1968	1970
		%E	%E
3SA-37	PBFS* No. 1	132	131
3SA-39		123	Lost
3SA-41		129	Lost
3SA-43		141	141
3SA-45		139	136
3SA-47		141	140
3SA-49		119	117
3SA-51		117	116
3SA-53		114	114
4SA-55	PBFS No. 2	138	134
4SA-57		126	Lost
4SA-59		129	128
4SA-61		135	135
4SA-63		140	139
4SA-65		137	137
4SA-67		139	135
4SA-69		114	113
4SA-71		114	114
5SA-73	PBFS No. 5	118	118
5SA-75		119	119
5SA-77		119	119
5SA-79		113	113
5SA-81		118	118
5SA-83		115	113
5SA-85		112	Lost
5SA-87		118	Lost
5SA-89		111	110
6SA-91	PBFS No. 6	123	123
6SA-93		131	131
6SA-95		125	123
6SA-97		127	125
6SA-99		126	Lost
6SA-101		119	Lost
6SA-103		131	Lost
6SA-105		132	Lost
6SA-107		129	Lost
7SA-109	PBFS No. 7	126	Lost
7SA-111		119	Lost
7SA-113		126	Lost
7SA-115		124	124
7SA-117		128	127
7SA-119		131	128
7SA-121		121	120
7SA-123		121	119
7SA-125		125	124
8SA-127	Type II PC**	124	122
8SA-129		120	118
8SA-131		121	121
8SA-133		121	119
8SA-135		122	122
8SA-137		116	115
8SA-139		118	117
8SA-141		138	138
8SA-143		128	128
9SA-145	PBFS No. 8	112	112
9SA-147		110	109
9SA-149		111	109
9SA-151		111	109
9SA-153		116	114
9SA-155		109	107
9SA-157		119	118
9SA-159		119	118
9SA-161		120	120
10SA-163	Blend: No. 2 PBFS, 80%; nat cem A, 20%†	121	121
10SA-165		107	105
10SA-167		122	121
10SA-169		110	109
10SA-171		123	121
10SA-173		117	115
10SA-175		121	121
10SA-177		118	117
10SA-179		131	130

(Continued)

\* Portland blast-furnace slag cement.

\*\* PC = portland cement.

† Nat cem = natural cement.

(Sheet 3)

(Revised Sept 1970)

Table 2-BFS (Concluded)

Section 11

Beam No.	Cement	1968	1970	Readings
		%E	%E	
11SA-181	Blend: No. 2 PFBS,* 75%; nat cem A, 25%†	125	123	
11SA-183		118	116	
11SA-185		126	126	
11SA-187		121	120	
11SA-189		132	131	
11SA-191		129	127	
11SA-193		112	111	
11SA-195		118	117	
11SA-197		131	131	
12SA-199	Blend: No. 2 PFBS, 70%; nat cem A, 30%	120	120	
12SA-201		110	110	
12SA-203		121	118	
12SA-205		129	128	
12SA-207		119	119	
12SA-209		124	122	
12SA-211		126	124	
12SA-213		125	125	

\* Portland blast-furnace slag cement.  
† Nat cement = natural cement.

Specimen Size-Frost Effects Investigation

In December 1968, 18 concrete specimens (four sizes) were installed on the Treat Island exposure rack. This installation consisted of nine 3-1/2- by 4-1/2- by 16-in. beams, three 6- by 6- by 30-in. beams, three 2-ft cubes, and three 18- by 18- by 36-in. prisms. The purpose of this installation was to develop data on the effect of specimen size on the durability of concrete specimens in tidal exposure.

The four sizes of concrete test specimens were made from six batches of the same concrete mixture. The mixture contained crushed limestone fine and coarse aggregates and had the following characteristics:

Coarse aggregate - 100% passing 1-in. sieve

Fine aggregate - 98-100% passing No. 4 sieve

Cement - type II portland

Air content -  $4\frac{1}{2} \pm 1\frac{1}{2}\%$

Water-cement ratio - 5.5 gal/bag

Slump -  $2\frac{1}{2} \pm 1\frac{1}{2}$  in.

Sand content - 36 to 42%

Cement factor -  $6.0 \pm 0.3$  bags/cu yd

Compressive strength at 28 days age (nominal) - 5000 psi

Table 1-SSFE lists these concrete specimens and gives their exposure record along with other pertinent information.

(Revised August 1977)

Table 1-SSFE

Section 12

## Record of Testing of Concrete Specimens for Specimen Size-Frost Effects Investigation

1968- (Installed Dec 1968)

Specimen No.	Air Content* %	1968-1975 Readings																Exposure Rack	
		0 Cycles, 1968				139 Cycles 1969		292 Cycles 1970		461 Cycles 1971		618 Cycles 1972		758 Cycles 1973		897 Cycles 1974		1009 Cycles 1975	
		Pulse Veloc		$\%V^2$		$\%E$		$\%V^2$		$\%E$		$\%V^2$		$\%E$		$\%V^2$		$\%E$	
		$\%E$	fps	$\%V^2$		$\%E$	$\%V^2$	$\%E$	$\%V^2$	$\%E$	$\%V^2$	$\%E$	$\%V^2$	$\%E$	$\%V^2$	$\%E$	$\%V^2$	$\%E$	$\%V^2$

## 3-1/2- by 4-1/2- by 16-in. Beams

ROS-4A	4.3	100	15,465	100	102	107	107	100	118	91	118	102	115	96	116	119	116	80
ROS-4B	4.3	100	15,930	100	104	99	110	96	119	82	119	96	117	94	118	110	118	57
ROS-4C	4.3	100	16,420	100	101	95	108	89	119	78	119	89	119	93	118	105	119	64
ROS-5A	4.6	100	15,740	100	102	104	108	101	118	86	120	94	121	101	120	95	118	66
ROS-5B	4.6	100	16,420	100	100	100	109	93	119	79	117	85	117	103	118	111	118	70
ROS-5C	4.6	100	16,420	100	99	95	110	91	120	83	118	91	118	98	119	105	118	70
ROS-6A	4.2**	100	16,120	100	101	99	111	94	119	84	117	96	117	96	116	105	117	73
ROS-6B	4.2**	100	16,320	100	100	94	110	88	118	75	116	90	118	99	120	103	120	70
ROS-6C	4.2**	100	16,320	100	101	90	110	84	117	75	115	84	120	104	119	105	120	67

## 6- by 6- by 30-in. Beams

ROS-1	4.0	100	14,795	100	100	114	115	112	111	92	109	99	109	112	109	127	109	152
ROS-2	4.4**	100	14,705	100	102	116	126	111	121	90	118	99	116	101	118	123	116	150
ROS-3	4.8	100	15,335	100	100	105	108	104	101	81	102	93	104	98	104	113	104	130

## 2-ft Cubes

ROS-1	4.0	100	15,210	100	†	101	†	99	†	82	†	101	†	102	†	119	†	150
ROS-2	4.4**	100	15,265	100	†	100	†	94	†	78	†	93	†	103	†	112	†	141
ROS-3	4.8	100	15,150	100	†	100	†	97	†	80	†	100	†	97	†	110	†	106

## 18- by 18- by 36-in. Prisms

ROS-4	4.3	100	15,750	100	94	102	106	99	107	89	105	95	108	105	109	105	109	109
ROS-5	4.6	100	15,545	100	94	102	102	100	114	87	116	99	116	105	116	108	116	111
ROS-6	4.2**	100	15,425	100	97	103	108	100	108	90	108	101	108	111	108	108	108	109

## 1976- Readings

Specimen No.	Air Content* %	1976				1977			
		Cycles		$\%E$		Cycles		$\%E$	
		$\%E$	$\%V^2$	$\%E$	$\%V^2$	$\%E$	$\%V^2$	$\%E$	$\%V^2$

## 3-1/2- by 4-1/2- by 16-in. Beams

ROS-4A	4.3	113	113	113	91				
ROS-4B	4.3	116	105	116	87				
ROS-4C	4.3	121	100	117	85				
ROS-5A	4.6	102	116	114	87				
ROS-5B	4.6	119	105	120	89				
ROS-5C	4.6	121	100	120	87				
ROS-6A	4.2**	118	98	117	93				
ROS-6B	4.2**	115	100	117	89				
ROS-6C	4.2**	117	105	117	70				

## 6- by 6- by 30-in. Beams

ROS-1	4.0	109	119	107	116				
ROS-2	4.4**	112	114	119	116				
ROS-3	4.8	100	100	102	101				

## 2-ft Cubes

ROS-1	4.0	†	112	†	112				
ROS-2	4.4**	†	100	†	106				
ROS-3	4.8	†	102	†	108				

## 18- by 18- by 36-in. Prisms

ROS-4	4.3	106	108	107	103				
ROS-5	4.6	118	110	118	106				
ROS-6	4.2**	112	110	112	104				

\* Air content determined on each batch; six batches of concrete were made for this investigation.

\*\* Slump was 2-1/4 in. for these batches; slump of all other batches of concrete was 2 in.

† Unable to obtain satisfactory flexural frequency reading on these cubes.

Trumbull Pond Dam Prisms

In June 1972, six concrete prisms (18 by 18 by 36 in.) were installed on the Treat Island exposure rack to determine the durability of two interior mass concrete mixtures containing the aggregate being considered for use in Trumbull Pond Dam.

The prisms were made from two concrete mixtures (three prisms per mixture); the fine and coarse aggregates used were pit-run sand and gravel, maximum size 6 in., from an undeveloped on-site source. Both concrete mixtures were air entrained ( $5 \pm 1$  percent) with a slump of  $2 \pm 1/2$  in. Type II portland cement was used in both mixtures, with one mixture containing a replacement material (35 percent by solid volume). Water-cement ratios were 0.66 and 0.63, by weight; cement factors were 2.90 and 3.15 bags per cu yd.

Table 1-TP lists these concrete specimens and gives their exposure record along with other pertinent information.

(Revised August 1977)

Table 1-TP

Section 13

Record of Testing of Trumbull Pond Dam Concrete Prisms

1972- (Installed June 1972)

Exposure Rack, Row 3														
Prism No.	Replacement Material	Water-Cement Ratio by Wt	Cementitious Material, lb/cu yd		1972-1975 Readings									
			Type II Portland Cement	Fly Ash	0 Cycles, 1972			140 Cycles		276 Cycles		388 Cycles		
					Pulse Velocity	%	fps	V <sup>2</sup>	1973		1974		1975	
									%	V <sup>2</sup>	%	V <sup>2</sup>	%	V <sup>2</sup>
Cem-1	None	0.66	273	0	100	13,760	100	113	111	113	103	109	98	
Cem-2	None	0.66	273	0	100	13,890	100	117	101	115	106	114	127	
Cem-3	None	0.66	273	0	100	14,220	100	101	108	100	105	99	126	
FA-1	Fly ash*	0.63	192	79	100	13,335	100	118	103	113	108	108	107	
FA-2	Fly ash*	0.63	192	79	100	13,275	100	125	116	121	106	116	98	
FA-3	Fly ash*	0.63	192	79	100	13,335	100	120	92	106	58	106	End gone	

Prism No.	Replacement Material	Water-Cement Ratio by Wt	Cementitious Material, lb/cu yd Type II Portland Cement	Fly Ash	1976- Readings			
					534 Cycles		611 Cycles	
					1976		1977	
					%E	%V <sup>2</sup>	%E	%V <sup>2</sup>
Cem-1	None	0.66	273	0	75	NR	NR	NR
Cem-2	None	0.66	273	0	109	102	77	106
Cem-3	None	0.66	273	0	100	91	47	97
FA-1	Fly ash*	0.63	192	79	119	NR	62	NR
FA-2	Fly ash*	0.63	192	79	106	NR	NR	NR
FA-3	Fly ash*	0.63	192	79	--	--	--	--

\* 35 percent replacement by solid volume; all prisms contain type II portland cement.  
NR denotes a satisfactory reading could not be obtained.

Investigation of 4-1/2-in. Aggregate Concrete

In December 1968, 12 concrete prisms (18 by 18 by 36 in.) were installed on the Treat Island exposure rack. The purpose of this installation was to determine the durability of mass concrete containing 4-1/2-in. maximum size aggregate.

The prisms were made from six concrete mixtures (two prisms per mixture); the fine and coarse aggregates used in all mixtures were of a crushed limestone, maximum size 4-1/2 in. Each concrete mixture was air-entrained ( $5 \pm 1\%$ ) with a slump of  $2 \pm 1/2$  in. Type II portland cement was used in all mixtures, and three mixtures also contained a replacement material (30% by solid volume). Water-cement ratios were 0.8, 0.9, or 1.0, by weight; cement factors varied from 1.84 to 2.40 bags per cu yd.

Table 1-4.5A lists these concrete specimens and gives their exposure record along with other pertinent information.

(Revised August 1977)

Table 1-4.5A

Section 14

## Record of Testing of Prisms Made for Investigation of 4-1/2-in. Aggregate Concrete

1968- (Installed Dec 1968)

Exposure Rack, Row 2															
Prism No.	Date Made	Replacement Material	Water-Cement Ratio by Wt	Cement Factor bags/cu yd	1968-1972 Readings										
					0 Cycles, 1968			139 Cycles 1969		292 Cycles 1970		461 Cycles 1971		618 Cycles 1972	
					%E	Pulse Veloc fps	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>
Mix 1, Rd 1	Oct 1967	None	0.8	2.30	100	16,130	100	87	102	106	99	105	73	91	62
Rd 2	Oct 1967	None	0.8	2.30	100	16,130	100	96	101	105	99	104	61	91	NR**
Mix 2, Rd 1	Nov 1967	None	0.9	2.04	100	15,705	100	99	103	102	100	101	83	89	81
Rd 2	Dec 1967	None	0.9	2.04	100	16,045	100	99	99	91	92	87	66	NR	43
Mix 3, Rd 1	Apr 1968	None	1.0	1.84	100	15,705	100	95	103	88	95	83	69	82	NR
Rd 2	July 1968	None	1.0	1.84	100	15,750	100	97	103	110	99	109	75	Failed	NR
Mix 4, Rd 1	Apr 1968	Fly ash*	0.8	2.40	100	16,440	100	93	104	122	98	108	76	110	86
Rd 2	July 1968	Fly ash*	0.8	2.40	100	16,045	100	89	99	120	96	116	79	111	91
Mix 5, Rd 1	June 1968	Fly ash*	0.9	2.14	100	15,790	100	95	111	106	107	106	86	99	96
Rd 2	July 1968	Fly ash*	0.9	2.14	100	15,665	100	90	108	103	105	103	84	100	65
Mix 6, Rd 1	July 1968	Fly ash*	1.0	1.94	100	15,625	100	101	102	65	97	Failed	78	Failed	58
Rd 2	July 1968	Fly ash*	1.0	1.94	100	15,545	100	97	107	105	96	103	75	84	84
1973-1977 Readings															
758 Cycles 1973		894 Cycles 1974		1006 Cycles 1975		1152 Cycles 1976		1229 Cycles 1977							
%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>
Mix 1, Rd 1	Oct 1967	None	0.8	2.30	77	86	75	61	72	67	93	14	90	18	
Rd 2	Oct 1967	None	0.8	2.30	NR	--	Failed								
Mix 2, Rd 1	Nov 1967	None	0.9	2.04	92	92	NR	98	Failed						
Rd 2	Dec 1967	None	0.9	2.04	Failed										
Mix 3, Rd 1	Apr 1968	None	1.0	1.84	NR	NR	Failed								
Rd 2	July 1968	None	1.0	1.84	Failed	NR									
Mix 4, Rd 1	Apr 1968	Fly ash*	0.8	2.40	101	98	92	92	92	95	95	37	--	Failed	
Rd 2	July 1968	Fly ash*	0.8	2.40	107	103	100	96	100	108	Failed				
Mix 5, Rd 1	June 1968	Fly ash*	0.9	2.14	95	111	86	103	86	111	66	50	73	48	
Rd 2	July 1968	Fly ash*	0.9	2.14	93	104	87	105	81	107	79	11	Failed		
Mix 6, Rd 1	July 1968	Fly ash*	1.0	1.94	Failed	95	Failed								
Rd 2	July 1968	Fly ash*	1.0	1.94	73	93	NR	78	Failed						

\* 30% replacement by solid volume; all prisms contain type II portland cement.

\*\* NR denotes a satisfactory reading could not be obtained.

(Issued August 1977)

Key to Section 15

Sulfur-Infiltrated Concrete (Canadian)

Aggregates: Coarse, limestone, Ottawa

Fine, natural sand, Ottawa Valley, Ottawa

Admixture: Air-entraining, DAREX, W. R. Grace

Cement: Type I (CSA type 10), Canada Cement La Farge,  
Hull, Quebec

Sulfur: 99.9 percent pure sulfur obtained commercially  
(Ottawa)

Sulfur-Infiltrated Concrete (Canadian)

In January 1976, the Canada Centre for Mineral and Energy Technology received permission from the Office, Chief of Engineers, to install specimens of sulfur-infiltrated concrete at the Treat Island exposure station.

In August 1976, eighteen 4- by 8-in. cylinders and thirty-six 3- by 6-in. cylinders were installed at half-tide elevation on the exposure rack. The cylinders were made from nine different concrete mixtures that included air-entrained and nonair-entrained concrete. The fine and coarse aggregates were natural sand and 1/2-in.-maximum size limestone, respectively. Type I (CSA Type 10) portland cement was used in the mixtures. Tables 1, 2, and 3 contain pertinent data on mixtures and specimens. Table 1-SIC contains the exposure records of installed specimens.

In July 1977, 15 sulfur-infiltrated precast concrete elements were installed as additions to the program. Pertinent data on these specimens will be included as the information becomes available.

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Table 1

Mix Data and Properties of Uninfiltrated Concrete Specimens

Mix Data					Properties of Fresh Concrete					Properties of Hardened Concrete (Uninfiltrated)				
Mix No.	Aggr Max Size in.	Fine/Coarse Aggr	Cement Content lb/cu yd	Water/Cement Ratio by Wt	Aggr/Cement	AEA cc/cu yd	Slump			1-Day Density lb/cu yd	3- x 6-in. Cylinder		4- x 8-in. Cylinder	
							in.	lb/cu yd	Air %		Compressive Strength,* psi 48-hr	Compressive Strength,* psi 28-day	Compressive Strength,* psi 48-hr	Compressive Strength,* psi 28-day
Nonair-Entrained Concrete														
81	1/2	50/50	490	0.69	6.4	--	5-1/2	3953	2.6	148	1260	3615	1375	3860
82	1/2	50/50	444	0.68	7.2	--	2	3942	2.8	148	1450	4030	1530	3920
83	1/2	50/50	443	0.68	7.2	--	2-1/2	3931	2.9	148	1505	4245	1410	3940
84	1/2	50/50	444	0.68	7.2	--	2-1/4	3942	2.5	148	1275	4035	1275	3840
85	1/2	50/50	444	0.68	7.2	--	1-3/4	3942	2.1	148	1380	4105	1375	3890
Air-Entrained Concrete														
86	1/2	50/50	414	0.61	7.2	80	3-1/2	3650	8.0	137	1090	3890	1275	3600
87	1/2	50/50	421	0.68	7.2	80	4-1/2	3737	8.0	138	1060	3060	1255	2895
88	1/2	50/50	384	0.67	7.9	80	3-1/2	3672	8.2	137	885	2725	1015	2630
89	1/2	50/50	392	0.67	7.9	80	3-1/2	3748	7.0	139	1025	2830	1095	2790

\* Average of two specimens.

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Table 2

Section 15

Infiltrated 3- x 6-in. Cylinders

Specimen No.	Density lb/cu yd	Sulfur		48-hr Compressive Strength psi
		g	%*	
81-5	157.4	187	11.8	11,040
81-6	156.9	184	11.7	10,475
81-7**	156.5	180	11.6	
81-8**	156.6	169	11.0	
81-9**	157.2	201	12.9	
81-10**	156.8	197	12.7	
82-5	157.7	191	12.3	11,605
82-6	158.0	197	12.8	11,180
82-7**	157.8	198	12.8	
82-8**	157.7	202	12.9	
82-9**	157.8	199	12.7	
82-10**	157.9	197	12.9	
83-5	156.6	197	12.6	11,040
83-6	157.2	203	13.2	10,900
83-7**	157.8	200	12.8	
83-8**	157.2	204	13.0	
83-9**	157.4	207	13.4	
83-10**	157.7	198	12.7	
84-5	158.2	200	12.7	10,970
84-6	156.2	205	13.2	11,325
84-7**	158.5	204	13.4	
84-8**	158.5	199	13.0	
84-9**	158.5	205	13.5	
84-10**	158.4	204	13.1	
85-5	157.6	209	13.6	12,170
85-6	158.2	206	13.3	11,605
85-7**	158.2	203	13.1	
85-8**	158.4	194	12.3	
85-9**	158.2	207	13.1	
85-10**	158.2	210	13.5	

(Continued)

\* Weight of sulfur/weight of dry specimen.

\*\* Exposed Treat Island specimens.

(Issued August 1977)

Table 2 (Continued)

Section 15

Specimen No.	Density lb/cu yd	Sulfur		48-hr Compressive Strength psi
		g	%*	
86-5	151.2	223	15.0	10,190
86-6	151.5	237	16.2	9,910
86-7**	150.3	236	16.1	
86-8**	150.2	226	15.6	
86-9**	151.3	239	16.5	
86-10**	151.5	252	17.9	
87-5	155.0	283	19.6	12,030
87-6	155.4	276	19.0	11,750
87-7**	154.5	286	19.9	
87-8**	155.0	284	19.6	
87-9**	154.9	285	19.7	
87-10**	155.6	282	19.3	
88-5	155.1	293	20.4	12,030
88-6	155.2	284	19.5	11,890
88-7**	155.0	281	19.7	
88-8**	155.1	291	20.5	
88-9**	155.0	294	20.5	
88-10**	154.9	288	20.3	
89-5	155.2	287	20.4	11,040
89-6	155.2	276	19.3	11,180
89-7**	155.9	279	19.1	
89-8**	155.5	277	19.2	
89-9**	155.7	276	18.9	
89-10**	155.7	278	19.6	

\* Weight of sulfur/weight of dry specimen.

\*\* Exposed Treat Island specimens.

(Issued August 1977)

Table 3  
Infiltrated 4- x 8-in. Cylinders

Section 15

Specimen No.	Density lb/cu yd	Sulfur		48-hr Compressive Strength psi
		g	%	
81-5	154.0	394	10.6	10,110
81-6*	153.5	369	9.9	
81-7*	153.9	386	10.4	
82-5	156.0	435	11.7	10,030
82-6*	155.2	416	11.1	
82-7*	156.1	438	12.0	
83-5	154.6	398	10.6	10,030
83-6*	153.8	388	10.7	
83-7*	154.1	411	11.1	
84-5	155.4	409	11.0	10,670
84-6*	155.3	401	10.9	
84-7*	155.9	412	11.1	
85-5	157.8	415	11.3	11,385
85-6*	157.4	449	12.3	
85-7*	156.9	447	12.3	
86-5	153.1	518	14.9	7,800
86-6*	146.2	446	13.1	
86-7*	146.3	460	13.2	
87-5	153.1	614	18.1	11,545
87-6*	154.0	641	18.6	
87-7*	152.4	591	17.1	
88-5	152.0	619	18.5	10,030
88-6*	152.2	604	17.5	
88-7*	152.5	592	17.2	
89-5	155.9	660	18.8	11,465
89-6*	156.0	638	18.3	
89-7*	155.7	641	18.6	

\* Exposed Treat Island specimens.

(Issued August 1977)

Table 1-SIC

Section 15

Sulfur-Infiltrated Concrete Specimens (Installed August 1976)

			1976-	Readings	Exposure Rack, Row 9
Specimen No.	0 Cycles, 1976 Pulse Veloc. fps	77 Cycles, 1977 %v <sup>2</sup>			
			<u>4- x 8-in. Cylinders</u>		
81-6	14,620	96			
82-6	15,360	89			
83-6	15,360	93			
84-6	15,505	87			
85-6	16,500	79			
86-6	14,185	80			
87-6	15,875	83			
88-6	15,505	86			
89-6	16,105	85			
81-7	15,150	88			
82-7	16,835	77			
83-7	15,360	89			
84-7	15,875	87			
85-7	16,665	81			
86-7	13,550	101			
87-7	16,180	78			
88-7	15,505	87			
89-7	16,025	85			
			<u>3- x 6-in. Cylinders</u>		
81-7	15,150	110			
81-8	14,880	120			
81-9	14,970	109			
81-10	15,060	108			
82-7	15,245	108			
82-8	15,430	106			
82-9	15,625	107			
82-10	15,625	107			
83-7	15,060	108			
83-8	15,245	105			
83-9	15,335	104			
83-10	15,245	102			
84-7	15,245	112			
84-8	15,825	98			
84-9	15,825	111			
84-10	15,430	109			
85-7	15,825	104			
85-8	15,430	109			
85-9	15,430	109			
85-10	15,060	115			
86-7	13,890	112			
86-8	14,285	106			
86-9	14,970	97			
86-10	14,795	112			
87-7	15,150	110			
87-8	14,705	117			
87-9	14,705	117			
87-10	14,705	109			
88-7	14,970	109			
88-8	14,880	120			
88-9	14,705	109			
88-10	14,880	120			
88-7	14,880	113			
89-8	14,970	102			
89-9	14,795	102			
89-10	14,970	102			

(Issued August 1977)

Key to Section 16

Roller Compacted Concrete

North Pacific Division - Walla Walla District

Aggregates: Coarse - natural minus 3-in. pit-run gravel, Benton County  
Pit. Fine-Benton County pit-run sand.

Air-Entraining Admixture: Neutralized vinsol Resin (NVX), Hercules  
Powder Co.

Cement: Sun Types I and II, Oregon Cement Co., Lime, Oreg.

(Issued August 1977)

Section 16

Roller Compacted Concrete

U. S. Army Engineer Division, North Pacific, U. S. Army  
Engineer District, Walla Walla, CE.

In July 1977, six roller compacted concrete beams (12 by 12 by 36 in.) were installed on the Treat Island exposure rack for the North Pacific Division Materials Laboratory. The mixes, No. 17257 and No. 17258, are considered as interior and exterior mixes, respectively, and were designed and tested for Zintel Canyon Optimum Gravity Dam (Walla Walla District), Kennewick, Wash. Portland cement types I and II and air-entraining admixture were used in both mixtures. Fine and coarse aggregates used were pit-run sand and gravel (natural minus 3 in.). Table 1-RCC gives the exposure record of the beams. More mixture data are given below:

Mix No.	Cement Content lb/cu yd	Water/ Cement Ratio	Vebe sec	A.E.A. ml/cu yd	Air	Theore- tical Unit Weight lb/cu ft	Compressive	
					Con- tent %		Strength, psi	
							28-day	90-day
17257	100	1.95	11	2000	2.4	153.8	610	1090
17258	200	0.98	17	1700	1.2	154.4	1920	2280

(Issued August 1977)

Section 16

Table 1-RCC

Record of Testing for Roller Compacted Concrete  
(Installed at Treat Island in August 1977)

Exposure Rack, Row 6

		1977-		Readings	
		0 Cycles, 1977			
Beam		Pulse			
No.	%E	Velocity			
		fps	%V <sup>2</sup>		
17257-7	100	13,160	100		
17257-8	100	12,930	100		
17257-9	100	13,045	100		
17258-7	100	14,020	100		
17258-8	100	14,150	100		
17258-9	100	14,425	100		

Longtime Study, Waterways Experiment Station\*

This study was initiated in FY 1955 in cooperation with the Portland Cement Association to investigate the durability of concretes containing selected cements. Eighteen beams (3-1/2 by 4-1/2 by 16 in.) were made with each of 22 cements, the cement factor being 6.0 bags per cu yd. The aggregates were a manufactured limestone sand and a limestone coarse aggregate. Resin soap was used as an air-entraining admixture in the amount necessary to give an air content of  $6 \pm 1/2\%$ .

In July 1955, half of these beams (198) were installed on the exposure rack at Treat Island, and the other half were installed on the exposure rack at St. Augustine in August 1955.

Table 1-LTS lists the specimens exposed at Treat Island and gives their exposure record along with their cements.

Table 2-LTS lists the specimens exposed at St. Augustine and gives their exposure record along with their cements.

Testing of specimens exposed at St. Augustine exposure station was discontinued after the 1970 inspection.

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\* See U. S. Army Engineer Waterways Experiment Station, CE, Cement Performance in Concrete, by Bryant Mather, Technical Report No. 6-787 (Vicksburg, Miss., September 1967).

(Revised Aug 1964)  
Table 1-LTS (Continued)

Section 17

Specimen No.		Cement Type	Pro-gram No.	Exposure Rack, Row 3 (W to E)																							
				1955-1964 Readings																							
				0 Cycles, 1955			167 Cycles 1956		311 Cycles 1957		382 Cycles 1958		532 Cycles 1959		603 Cycles 1960		744 Cycles 1961		833 Cycles 1962		939 Cycles 1963		1074 Cycles 1964				
				FE	rps	W <sup>2</sup>	FE	W <sup>2</sup>	FE	W <sup>2</sup>	FE	W <sup>2</sup>	FE	W <sup>2</sup>	FE	W <sup>2</sup>	FE	W <sup>2</sup>	FE	W <sup>2</sup>	FE	W <sup>2</sup>	FE	W <sup>2</sup>	FE	W <sup>2</sup>	
5741C	III	33†	100	15,080	100	104	98	103	107	110	108	111	93	112	101	106	100	110	113	111	101	111	103				
5742C			100	14,980	100	106	99	105	107	111	116	112	92	113	104	Lost											
5743C			100	15,080	100	103	99	102	106	108	113	109	95	111	104	106	99	109	111	112	121	112	104				
5744C	I	14**	100	15,645	100	119	96	118	105	126	108	125	90	125	103	116	94	120	105	122	117	121	105				
5745C			100	15,535	100	106	96	107	105	114	113	113	92	114	104	107	95	110	110	112	111	112	105				
5746C			100	15,465	100	107	99	105	104	113	115	113	93	114	106	108	100	111	109	114	116	113	112				
5747C	II	24**	100	15,180	100	111	103	109	107	117	115	118	94	118	106	112	106	114	114	115	116	117	110				
5748C			100	15,215	100	111	103	110	106	117	112	118	91	118	104	111	103	115	113	118	113	117	103				
5749C			100	15,320	100	108	102	107	108	114	112	114	89	115	105	109	100	111	113	117	113	113	101				
5750C	I	19A	100	14,680	100	114	106	113	112	120	120	120	96	121	108	115	105	120	117	122	121	121	113				
5751C			100	14,650	100	113	105	112	112	120	114	121	97	122	110	117	105	118	114	126	123	126	114				
5752C			100	14,715	100	113	108	113	116	121	120	122	102	123	112	117	109	122	113	123	116	123	117				
5753C	I	18	100	15,115	100	113	107	102	112	118	116	119	96	119	110	112	103	114	118	114	123	112	104				
5754C			100	15,115	100	112	104	111	111	118	118	119	96	119	108	113	107	115	119	118	121	113	102				
5755C			100	15,045	100	110	107	109	109	116	117	117	94	118	108	113	108	116	119	119	124	115	110				
5756C	IV	43*	100	14,650	100	117	110	116	113	124	121	125	98	125	109	118	112	121	118	127	120	126	114				
5757C			100	14,810	100	116	108	116	115	123	121	124	97	124	107	116	107	118	118	121	120	120	111				
5758C			100	14,980	100	114	106	112	110	120	120	121	98	120	107	114	101	116	116	117	119	115	109				
5759C	II	22††	100	15,465	100	111	105	110	107	117	120	117	94	119	106	113	100	117	119	120	109	120	110				
5760C			100	15,465	100	112	107	109	109	117	118	119	94	120	107	115	118	118	116	119	105	119	109				
5761C			100	15,395	100	119	108	117	111	125	121	127	95	128	105	123	108	128	109	129	106	128	107				
5762C	IV	43*	100	14,945	100	117	115	116	116	123	124	124	95	124	108	117	110	120	118	121	113	121	113				
5763C			100	15,150	100	117	111	115	111	123	121	122	97	122	107	114	108	113	117	112	127	112	110				
5764C			100	15,150	100	114	113	113	109	120	118	121	95	122	107	116	106	120	117	120	119	122	107				
5765C	II	25†	100	15,150	100	112	114	110	111	117	115	118	101	119	108	113	103	115	113	118	118	117	109				
5766C			100	15,395	100	112	110	111	108	120	119	121	94	122	106	116	104	120	116	125	115	121	107				
5767C			100	15,535	100	111	107	111	111	117	114	118	89	118	103	114	100	115	113	117	112	116	104				
5768C	II	23	100	15,755	100	105	106	104	107	110	109	112	89	112	104	107	101	110	110	110	104	106	101				
5769C			100	15,795	100	107	103	105	109	112	108	113	85	114	101	108	100	111	109	114	101	111	100				
5770C			100	15,830	100	105	96	104	107	110	107	111	86	112	101	108	100	111	110	110	106	110	98				
5771C	I	17	100	15,755	100	106	97	104	103	110	108	111	90	112	99	106	100	108	111	107	107	108	99				
5772C			100	15,505	100	106	103	105	106	112	111	112	90	113	103	108	104	112	113	112	117	112	104				
5773C			100	15,395	100	104	103	102	109	108	117	108	89	107	104	101	103	105	101	106	117	101	103				
5774C	IV	43A*	100	14,845	100	118	101	116	104	125	110	127	90	128	102	121	111	123	115	125	133	126	118				
5775C			100	14,845	100	118	116	118	116	124	122	125	100	126	114	119	114	123	127	125	133	124	120				
5776C			100	14,585	100	122	122	121	120	129	131	130	101	133	118	126	114	129	123	132	118	132	122				
5777C	I	16	100	15,150	100	107	111	105	108	113	119	116	94	115	107	110	110	114	103	116	122	117	112				
5778C			100	15,320	100	108	108	107	111	114	118	115	91	116	106	109	103	113	104	115	128	115	104				
5779C			100	15,430	100	109	107	107	109	114	118	116	91	117	106	111	105	115	112	116	111	119	102				
5780C	III	31††	100	14,980	100	106	106	105	110	111	115	113	97	113	108	107	111	112	110	115	118	114	102				
5781C			100	14,910	100	109	107	108	109	112	119	111	96	113	107	108	109	114	112	119	108	117	106				
5782C			100	14,945	100	109	105	107	108	114	116	114	92	115	108	112	105	118	106	123	118	124	106				
5783C	III	33†	100	15,115	100	105	104	104	105	110	110	112	94	113	104	108	99	114	113	117	115	115	107				
5784C			100	15,115	100	105	102	104	104	109	111	113	91	113	103	108	102	114	107	116	115	118	109				
5785C			100	15,355	100	104	102	103	103	110	109	111	92	112	102	107	97	113	104	116	114	116	107				
5786C	I	12††	100	15,680	100	104	104	101	107	113	117	107	93	106	105	98	95	100	108	102	105	99	102				
5787C			100	15,720	100	105	105	102	109	108	116	108	92	107	104	100	102	102	104	102	112	102	100				
5788C			100	15,755	100	107	103	105	110	111	117	112	86	111	103	104	99	106	107	108	109	106	106				
5789C	I	19B	100	15,795	100	106	99	104	104	110	109	112	83	112	95	107	99	112	104	113	106	113	102				
5790C			100	15,355	100	105	106	104	108	110	113	111	90	110	102	105	101	109	115	111	109	111	109				
5791C			100	15,505	100	105	102	102	109	109	117	111	90	111	104	105	100	108	110	111	105	109	104				
5792C	I	19C	100	15,570	100	107	101	105	106	111	113	112	92	114	98	107	101	111	110	113	99	113	96				
5793C			100	15,505	100	106	103	104	104	111	114	113	93	112	96	1											

(Revised Aug 1964)  
Table 1-LTS (Continued)

Section 17

		Exposure Rack, Row 3 (W to E)																					
		1955-1964 Readings																					
Specimen No.	Cement Type	Program No.	0 Cycles, 1955			167 Cycles 1956		311 Cycles 1957		382 Cycles 1958		532 Cycles 1959		603 Cycles 1960		744 Cycles 1961		833 Cycles 1962		939 Cycles 1963		1074 Cycles 1964	
			FE	Pulse Veloc fps	FE <sup>2</sup>	FE	FE <sup>2</sup>	FE	FE <sup>2</sup>	FE	FE <sup>2</sup>	FE	FE <sup>2</sup>	FE	FE <sup>2</sup>	FE	FE <sup>2</sup>	FE	FE <sup>2</sup>	FE	FE <sup>2</sup>	FE	FE <sup>2</sup>
5795C	I	14**	100	15,720	100	105	99	104	101	110	112	110	87	111	97	106	97	122	107	124	102	123	101
5796C			100	15,985	100	100	97	99	99	104	111	105	85	106	95	101	96	104	105	106	107	103	100
5797C			100	15,795	100	101	101	100	100	103	111	103	88	104	88	100	101	103	106	106	101	101	103
5798C	I	11	100	15,645	100	105	104	104	103	109	111	109	89	110	101	105	103	108	107	113	105	112	105
5799C			100	15,720	100	108	104	104	105	112	113	114	87	115	100	110	99	114	107	120	108	117	101
5800C			100	15,720	100	106	103	104	104	111	115	112	88	113	98	108	105	112	105	115	112	115	101
5801C	II	21	100	15,335	100	107	101	105	107	113	115	113	92	114	106	109	97	113	106	116	112	115	106
5802C			100	15,570	100	106	100	105	104	111	117	111	95	111	97	106	103	108	108	110	107	110	101
5803C			100	15,830	100	105	97	104	103	109	110	110	90	111	100	106	99	109	107	110	98	110	104
5804C	V	51	100	15,795	100	107	99	105	103	112	115	113	92	113	101	107	97	109	103	109	112	110	100
5805C			100	15,465	100	107	104	107	105	113	118	115	93	114	104	107	103	110	118	111	115	111	98
5806C			100	15,535	100	107	101	106	103	113	115	114	92	113	103	106	103	109	114	108	104	108	93
5807C	I	18	100	15,680	100	102	101	101	101	107	111	107	91	106	101	101	101	102	116	103	107	101	91
5808C			100	15,465	100	108	104	107	102	113	116	115	95	115	103	112	112	115	115	119	113	117	93
5809C			100	15,180	100	106	105	105	105	112	114	112	97	111	105	106	106	109	118	113	114	109	97
5810C	II	24**	100	15,465	100	105	101	103	99	109	107	108	89	107	99	101	99	106	106	107	109	107	93
5811C			100	15,570	100	103	102	102	102	108	108	108	89	107	98	101	97	105	106	107	99	106	94
5812C			100	15,570	100	108	101	106	104	113	108	114	89	113	96	107	99	110	108	115	110	113	102
5813C	I	13	100	15,505	100	106	104	105	107	112	114	112	90	111	101	104	99	108	100	109	107	108	99
5814C			100	15,795	100	105	100	103	101	109	109	108	87	105	96	97	91	98	109	99	101	96	98
5815C			100	15,535	100	106	103	105	105	109	116	110	92	108	97	100	95	104	109	102	104	105	100
5816C	IV	41**	100	15,285	100	111	106	110	106	115	109	117	95	117	104	111	98	115	110	122	103	117	100
5817C			100	15,795	100	106	98	105	99	110	105	111	89	112	96	105	95	108	107	110	112	110	98
5818C			100	15,355	100	108	100	107	102	111	116	113	91	113	101	108	103	111	109	111	112	111	105
5819C	I	19A	100	14,910	100	108	107	107	105	111	122	113	91	115	104	109	105	113	115	117	113	117	104
5820C			100	14,945	100	110	108	110	103	114	120	118	97	118	104	113	103	118	106	121	103	121	111
5821C			100	14,910	100	112	109	111	115	115	122	120	96	121	107	115	110	120	118	122	113	120	101
5822C	I	15	100	15,795	100	102	100	101	101	103	113	105	88	106	98	100	99	103	113	106	111	105	98
5823C			100	15,720	100	101	102	99	100	102	106	103	89	104	101	99	97	102	112	103	107	102	106
5824C			100	15,680	100	103	103	102	101	105	112	107	91	109	98	103	92	105	111	106	105	105	99
5825C	I	19C	100	15,250	100	103	105	102	101	106	103	107	94	110	103	105	103	108	112	112	115	111	103
5826C			100	15,320	100	104	104	103	102	106	111	108	93	110	100	105	101	109	116	111	110	112	107
5827C			100	15,215	100	104	106	104	105	107	116	109	94	110	104	105	110	109	112	111	113	109	97
5828C	I	11	100	16,020	100	101	101	99	97	105	108	107	85	109	101	105	97	108	102	111	117	110	102
5829C			100	16,060	100	99	98	98	97	102	110	104	87	106	96	102	98	105	99	109	110	106	99
5830C			100	15,535	100	102	105	101	102	105	117	107	100	106	103	101	98	104	110	107	104	108	102
5831C	I	19A	100	15,180	100	107	104	106	105	111	118	113	94	113	104	106	104	109	112	111	108	109	108
5832C			100	15,250	100	106	103	105	109	110	118	112	95	111	102	104	100	108	117	110	108	108	105
5833C			100	15,080	100	108	103	108	108	113	115	116	97	118	102	112	103	116	107	118	106	118	102
5834C	IV	43A*	100	14,845	100	113	110	113	114	119	125	121	101	122	110	114	109	117	112	118	114	116	119
5835C			100	14,945	100	112	111	113	117	117	125	120	99	121	109	114	110	118	115	119	120	119	118
5836C			100	15,535	100	111	101	110	102	117	113	119	92	120	101	113	104	115	113	115	107	116	106
5837C	I	18	100	15,610	100	108	99	106	100	112	114	116	90	115	98	108	100	111	104	111	117	109	104
5838C			100	15,320	100	108	105	107	103	112	117	114	95	116	105	111	105	114	109	115	110	116	103
5839C			100	15,570	100	106	101	107	100	110	115	112	92	112	99	105	115	107	106	104	106	95	
5840C	I	15	100	15,720	100	102	98	101	101	106	112	107	93	106	99	99	93	97	106	100	93	100	93
5841C			100	15,755	100	104	97	102	98	107	110	110	91	110	98	104	99	107	95	106	99	106	92
5842C			100	15,645	100	102	98	102	101	105	108	107	98	107	100	99	91	101	102	100	98	97	92
5843C	III	33†	100	15,215	100	102	99	100	101	104	114	106	95	107	97	101	105	105	106	105	111	106	91
5844C			100	15,395	100	103	98	101	99	106	113	108	90	109	97	105	97	106	103	111	104	109	88
5845C			100	15,355	100	103	98	102	99	107	114	108	92	109	97	104	93	107	103	112	113	111	100
5846C	IV	43*	100	14,980	100	111	107	111	102	115	121	117	96	117	103	112	105	114	114	117	118	115	111
5847C			100	15,250	100	107	104	106	100	111	118	112	92	110	104	103	99	102	111	100	111	100	103
5848C			100	15,610	100	105	98	104	97	108	113	109	89	107	97	100	105	105	107	99	111	101	99

(Continued)

\* Cements 43 and 43A made at same plant.  
\*\* Cements 14, 24, and 41 made at same plant.  
† Cements 25 and 33 made from same major raw materials.

(Revised Aug 1965)

Table 1-LTS (Continued)

Section 17

Specimen No.	Cement Type	Program No.	1955-1964 Readings																							
			0 Cycles, 1955			167 Cycles 1956		311 Cycles 1957		382 Cycles 1958		532 Cycles 1959		603 Cycles 1960		744 Cycles 1961		833 Cycles 1962		939 Cycles 1963		1074 Cycles 1964				
			Pulse Veloc																							
			FE	fps	EV <sup>2</sup>	FE	EV <sup>2</sup>	FE	EV <sup>2</sup>	FE	EV <sup>2</sup>	FE	EV <sup>2</sup>	FE	EV <sup>2</sup>	FE	EV <sup>2</sup>	FE	EV <sup>2</sup>	FE	EV <sup>2</sup>	FE	EV <sup>2</sup>			
5849C	I	16	100	15,985	100	100	92	100	92	103	117	104	89	107	103	103	95	106	109	106	99	107	100			
5850C			100	15,680	100	105	97	105	99	109	116	113	90	114	101	109	102	111	107	116	110	116	102			
5851C			100	15,830	100	105	96	105	93	109	117	110	90	111	98	107	96	110	111	111	117	109	100			
5852C	I	13	100	15,505	100	106	99	106	105	110	122	112	93	111	102	105	99	110	114	110	110	110	102			
5853C			100	15,795	100	105	97	104	102	108	115	111	90	110	96	104	100	109	106	108	111	108	99			
5854C			100	15,535	100	107	97	107	106	111	119	113	93	113	101	107	93	110	103	111	112	106	108			
5855C	III	31++	100	15,045	100	105	105	103	105	105	122	108	94	109	104	104	98	107	107	107	114	106	108			
5856C			100	15,115	100	103	99	101	92	105	93	104	92	103	101	98	96	97	96	100	110	99	102			
5857C			100	14,910	100	103	105	101	104	104	118	107	96	108	103	102	105	105	106	108	113	107	105			
5858C	II	24**	100	15,285	100	106	100	106	101	110	118	110	90	112	101	108	102	110	107	113	110	113	104			
5859C			100	15,320	100	106	98	106	99	110	114	110	90	111	96	106	100	113	105	113	105	111	107			
5860C			100	15,570	100	102	97	100	98	103	114	102	89	100	92	94	96	96	104	94	109	91	103			
5861C	I	14**	100	15,320	100	105	102	103	100	108	118	109	92	108	96	101	94	105	105	105	110	104	99			
5862C			100	15,795	100	104	98	103	96	108	110	109	85	108	92	104	92	108	99	111	101	108	100			
5863C			100	15,465	100	105	100	105	102	110	116	111	90	111	99	106	93	109	108	110	110	110	105			
5864C	II	23	100	15,610	100	104	98	103	100	107	115	109	89	109	99	104	98	107	101	109	107	107	103			
5865C			100	15,645	100	102	98	102	101	106	113	107	87	105	99	98	96	101	103	100	113	100	95			
5866C			100	15,905	100	101	91	100	98	105	115	107	88	105	102	98	96	101	101	102	109	100	93			
5867C	II	21	100	15,180	100	105	105	105	105	110	117	112	94	111	106	107	104	109	107	109	115	109	109			
5868C			100	15,250	100	107	101	107	103	112	120	114	92	113	103	107	104	111	107	112	115	109	108			
5869C			100	15,180	100	107	104	106	101	112	120	114	94	115	106	110	106	113	109	115	115	113	108			
5870C	I	19B	100	15,320	100	105	102	104	99	108	118	110	94	110	103	106	105	111	109	112	118	110	102			
5871C			100	15,795	100	105	98	104	95	107	110	109	86	112	95	108	93	112	101	113	111	111	95			
5872C			100	15,795	100	102	101	101	96	104	109	105	86	104	93	99	92	102	99	103	105	101	94			
5873C	I	12++	100	15,870	100	100	96	98	97	100	117	100	88	98	96	92	96	94	98	92	100	92	91			
5874C			100	15,830	100	101	98	100	99	104	117	105	90	105	98	100	92	103	111	104	105	100	101			
5875C			100	15,505	100	105	101	104	104	108	121	110	91	111	99	106	100	110	110	113	110	112	107			
5876C	V	51	100	15,285	100	106	104	106	107	113	123	115	94	115	102	108	106	111	115	110	119	109	110			
5877C			100	15,320	100	106	102	105	105	111	121	112	94	111	103	103	100	106	113	106	119	103	104			
5878C			100	15,180	100	111	100	112	108	117	124	119	97	121	108	115	105	118	116	117	118	118	111			
5879C	IV	41**	100	15,215	100	109	100	109	104	115	123	115	94	116	107	110	100	114	110	115	116	114	100			
5880C			100	15,010	100	110	102	110	107	114	123	115	94	116	104	109	99	115	113	113	114	114	110			
5881C			100	15,355	100	107	101	106	101	111	117	111	88	112	99	107	101	109	98	108	111	106	100			
5882C	I	17	100	15,795	100	104	94	104	96	108	113	110	90	111	96	104	99	108	106	106	106	103	103			
5883C			100	15,535	100	106	98	104	101	110	122	112	93	112	100	107	99	109	103	110	107	110	101			
5884C			100	15,570	100	103	98	102	99	106	117	109	99	110	101	105	97	109	107	110	112	107	99			
5885C	II	25+	100	15,395	100	106	101	104	102	112	119	114	96	114	96	108	103	110	107	112	117	112	107			
5886C			100	15,355	100	108	105	107	105	112	122	113	97	114	105	108	101	112	109	113	118	113	110			
5887C			100	15,250	100	109	105	111	105	114	121	116	103	117	104	114	107	118	106	119	119	121	108			
5888C	II	22++	100	15,795	100	111	98	111	99	115	115	117	89	118	99	114	99	119	109	118	111	118	102			
5889C			100	15,355	100	106	105	105	104	109	103	111	87	111	90	106	103	108	113	110	118	108	109			
5890C			100	15,505	100	107	105	105	102	112	113	114	93	114	103	110	102	116	105	124	114	126	107			

(Continued)

\*\* Cements 14, 24, and 41 made at same plant.

† Cements 25 and 33 made from same major raw materials.

++ Cements 12, 22, and 31 made at same plant.

(Sheet 4)

(Revised May 1976)

Table 1-LTS (Continued)

Section 17

(Installed at Treat Island in July 1955)

Specimen No.	Cement Type	Pro-gram No.	1965-1974 Readings															
			1237		1367		1523		1708		1862		2015		2184		2341	
			Cycles 1965		Cycles 1966		Cycles 1967		Cycles 1968		Cycles 1969		Cycles 1970		Cycles 1971		Cycles 1972	
			$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$
5693C	IV	43A*	121	127	122	131	120	125	119	133	116	122	116	113	114	*	109	*
5694C			118	125	120	129	115	123	120	136	115	123	119	112	119	*	123	*
5695C			114	121	115	129	113	121	111	128	107	109	105	99	97	*	95	*
5696C	II	21	108	100	106	120	106	113	104	118	102	106	104	99	100	*	98	*
5697C			111	121	112	109	111	118	111	121	109	106	111	97	109	*	108	*
5698C			112	122	109	124	107	120	111	128	109	115	108	105	108	*	101	*
5699C	IV	41**	116	119	113	126	112	114	113	125	111	107	112	95	114	*	107	*
5700C			116	119	114	110	114	112	115	115	114	107	115	98	115	*	113	*
5701C			111	113	111	110	109	108	111	117	107	105	107	96	107	*	105	*
5702C	I	16	104	108	106	103	100	100	101	110	101	94	99	88	99	*	103	*
5703C			103	112	102	111	102	102	101	111	99	94	98	84	98	*	101	*
5704C			103	105	102	109	100	104	102	111	100	94	102	82	*	*	108	*
5705C	V	51	104	115	104	109	102	112	100	123	98	102	101	91	94	*	89	*
5706C			99	122	101	115	99	111	95	121	94	102	91	93	83	*	80	*
5707C			100	118	98	114	96	107	93	117	91	101	91	90	83	*	80	*
5708C	I	13	96	127	97	100	96	110	94	116	94	98	97	88	95	*	93	*
5709C			107	120	103	122	102	111	101	118	99	100	102	92	100	*	96	*
5710C			109	117	109	122	106	108	107	116	105	105	104	92	103	*	101	*
5711C	I	11	113	115	113	121	113	109	114	111	112	107	112	91	111	*	110	*
5712C			112	116	112	109	112	108	113	109	111	104	114	95	*	*	127	*
5713C			114	111	114	110	113	105	111	110	110	100	114	90	*	*	128	*
5714C	II	23	119	122	119	121	119	115	121	121	119	102	122	94	130	*	128	*
5715C			112	NR	114	114	114	109	116	119	116	103	120	94	125	*	124	*
5716C			115	115	115	106	115	108	118	112	116	96	119	90	127	*	125	*
5717C	II	25†	124	115	124	113	124	115	126	122	126	106	131	96	133	*	132	*
5718C			120	128	122	109	122	116	122	120	120	109	127	99	132	*	128	*
5719C			119	125	119	104	120	111	120	112	120	107	126	95	129	*	128	*
5720C	I	19B	113	115	114	103	115	103	117	104	116	92	123	81	123	*	123	*
5721C			114	114	114	102	114	111	116	116	118	102	123	93	125	*	123	*
5722C			117	114	116	111	115	112	118	116	118	103	123	92	128	*	126	*
5723C	I	19C	118	115	121	106	120	109	120	114	120	99	125	90	125	*	130	*
5724C			114	116	114	109	115	116	115	118	114	99	114	95	124	*	122	*
5725C			116	122	116	110	117	118	117	115	115	103	119	89	119	*	127	*
5726C	I	12††	119	122	119	116	120	116	119	107	119	96	124	87	131	*	129	*
5727C			119	120	121	113	121	113	120	105	120	98	123	89	130	*	129	*
5728C			116	118	117	111	117	115	118	106	118	96	122	90	127	*	126	*
5729C	I	17	115	118	115	110	114	113	114	111	112	102	116	96	124	*	122	*
5730C			108	125	109	117	109	115	109	112	108	95	112	89	118	*	116	*
5731C			109	121	110	115	110	117	109	113	110	102	116	96	114	*	114	*
5732C	III	31††	113	126	115	117	114	114	117	109	117	*	124	*	133	*	132	*
5733C			113	127	114	107	112	113	117	108	117	*	122	*	140	*	146	*
5734C			113	118	118	92	118	113	121	113	123	*	130	*	138	*	143	*
5735C	I	15	106	116	110	106	111	110	111	102	112	*	116	*	124	*	126	*
5736C			100	118	100	107	99	110	101	112	100	*	102	*	108	*	105	*
5737C			102	115	101	99	101	112	103	108	103	*	105	*	108	*	102	*
5738C	II	22††	118	120	117	122	117	116	119	116	117	*	124	*	132	*	125	*
5739C			121	128	123	110	122	124	124	122	126	*	133	*	133	*	136	*
5740C			124	122	126	105	125	118	127	124	123	*	135	*	138	*	134	*

(Continued)

- \* Cements 43 and 43A made at same plant.  
 \*\* Cements 14, 24, and 41 made at same plant.  
 † Cements 25 and 33 made from same major raw materials.  
 †† Cements 12, 22, and 31 made at same plant.  
 NR Reading was not taken due to oversight.  
 \* End of specimen too rough to obtain satisfactory reading.

(Sheet 5)

(Revised May 1976)

Table 1-LTS (Continued)

Section 17

(Installed At Treat Island in July 1955)

Specimen No.	Cement Type	Pro-gram No.	1965-1974 Readings															
			1237		1367		1523		1708		1862		2015		2184		2341	
			Cycles 1965	$\frac{E}{V^2}$	Cycles 1966	$\frac{E}{V^2}$	Cycles 1967	$\frac{E}{V^2}$	Cycles 1968	$\frac{E}{V^2}$	Cycles 1969	$\frac{E}{V^2}$	Cycles 1970	$\frac{E}{V^2}$	Cycles 1971	$\frac{E}{V^2}$	Cycles 1972	$\frac{E}{V^2}$
5741C	III	33†	109	126	111	101	111	120	114	109	114	*	120	*	*	*	141	*
5743C			112	106	115	106	115	117	116	116	118	*	122	*	123	*	139	*
5744C	I	14**	116	109	120	103	118	108	118	109	119	*	124	*	124	*	119	*
5745C			110	117	113	107	113	109	113	115	115	*	120	*	120	*	115	*
5746C			113	119	113	120	114	114	114	122	115	*	122	*	122	*	113	*
5747C	II	24**	115	119	116	112	116	114	116	122	115	*	122	*	122	*	117	*
5748C			118	118	118	120	117	112	117	122	117	*	124	*	126	*	118	*
5749C			114	113	115	124	116	116	114	124	116	*	123	*	121	*	108	*
5750C	I	19A	121	125	122	132	121	121	120	104	120	*	126	*	129	*	131	*
5751C			126	121	128	136	128	118	129	112	131	*	138	*	140	*	133	*
5752C			123	123	127	128	127	122	127	116	127	*	132	*	136	*	137	*
5753C	I	18	110	120	110	110	112	99	112	100	114	*	121	*	123	*	118	*
5754C			111	127	114	116	115	111	113	103	115	*	122	*	121	*	115	*
5755C			114	118	112	123	112	112	114	108	112	*	119	*	126	*	118	*
5756C	IV	43*	124	130	124	129	124	120	124	117	126	*	131	*	132	*	131	*
5757C			120	125	122	127	122	116	120	117	122	*	127	*	129	*	125	*
5758C			117	121	118	124	117	118	118	111	117	*	124	*	128	*	123	*
5759C	II	22††	119	113	119	125	119	111	118	113	117	*	124	*	130	*	123	*
5760C			119	121	118	125	117	112	117	113	117	*	124	*	125	*	124	*
5761C			129	123	133	109	132	112	132	114	133	*	138	*	142	*	139	*
5762C	IV	43*	121	125	123	131	123	110	122	117	123	*	130	*	130	*	118	*
5763C			110	122	113	110	114	115	111	111	113	*	120	*	120	*	119	*
5764C			122	121	123	121	123	115	123	112	124	*	131	*	137	*	130	*
5765C	II	25†	118	124	118	121	118	115	118	112	118	*	127	*	129	*	127	*
5766C			122	112	123	106	123	113	123	112	124	*	131	*	131	*	129	*
5767C			117	115	118	118	119	114	118	110	117	*	123	*	125	*	123	*
5768C	II	23	110	118	110	106	111	111	109	109	108	*	114	*	120	*	116	*
5769C			111	116	111	114	112	111	111	107	112	*	116	*	122	*	116	*
5770C			111	116	113	108	113	111	115	105	117	*	124	*	126	*	131	*
5771C	I	17	106	122	105	106	106	113	106	100	107	*	109	*	109	*	107	*
5772C			109	116	111	116	112	110	111	104	112	*	116	*	115	*	111	*
5773C			104	120	105	109	106	109	102	106	104	*	100	*	104	*	104	*
5774C	IV	43A*	127	126	127	107	127	117	126	123	127	*	134	*	135	*	129	*
5775C			122	118	122	117	122	120	122	114	123	*	128	*	125	*	136	*
5776C			135	135	132	118	131	127	135	131	135	*	143	*	145	*	144	*
5777C	I	16	119	126	117	107	117	102	117	102	119	*	126	*	126	*	123	*
5778C			110	124	113	113	114	113	114	113	115	*	119	*	122	*	118	*
5779C			117	NR	117	114	116	112	117	111	115	*	117	*	125	*	126	*
5780C	III	31††	108	128	110	98	110	*	114	*	115	*	118	*	124	*	123	*
5781C			118	126	119	94	119	*	124	*	124	*	129	*	141	*	140	*
5782C			122	122	128	100	127	*	128	*	127	*	135	*	145	*	134	*
5783C	III	33†	118	120	118	96	118	*	119	*	120	*	125	*	137	*	133	*
5784C			119	113	119	103	119	108	121	106	123	*	130	*	142	*	141	*
5785C			116	113	115	97	117	104	119	103	119	*	126	*	137	*	138	*
5786C	I	12††	99	113	99	95	100	105	97	102	99	*	103	*	100	*	95	*
5787C			101	105	103	100	104	100	101	97	99	*	103	*	109	*	111	*
5788C			105	116	106	99	107	104	104	102	106	*	110	*	112	*	110	*
5789C	I	19B	113	112	113	92	113	101	112	101	111	*	115	*	121	*	112	*
5790C			111	119	110	107	110	108	109	107	110	*	116	*	118	*	126	*
5791C			111	108	110	105	110	105	110	105	111	*	115	*	116	*	115	*
5792C	I	19C	111	106	111	85	113	95	114	97	115	*	119	*	126	*	120	*
5793C			113	115	115	89	114	100	117	98	117	*	124	*	134	*	133	*
5794C			131	116	132	90	131	105	133	103	131	*	138	*	148	*	148	*

(Continued)

\* Cements 43 and 43A made at same plant.

\*\* Cements 14, 24, and 41 made at same plant.

† Cements 25 and 33 made from same major raw materials.

†† Cements 12, 22, and 31 made at same plant.

NR No reading taken due to oversight.

\* End of specimen too rough to obtain satisfactory reading.

(Sheet 6)

(Revised May 1976)

Table 1-LTS (Continued)

Section 17

(Installed at Treat Island in July 1955)

Specimen No.		Cement Type	Pro-gram No.	1965-1974 Readings																							
				1237 Cycles 1965		1367 Cycles 1966		1523 Cycles 1967		1708 Cycles 1968		1862 Cycles 1969		2015 Cycles 1970		2184 Cycles 1971		2341 Cycles 1972		2481 Cycles 1973		2617 Cycles 1974					
				FE	SV <sup>2</sup>	FE	SV <sup>2</sup>	FE	SV <sup>2</sup>	FE	SV <sup>2</sup>	FE	SV <sup>2</sup>	FE	SV <sup>2</sup>	FE	SV <sup>2</sup>	FE	SV <sup>2</sup>	FE	SV <sup>2</sup>	FE	SV <sup>2</sup>				
5795C	I	14**	124	101	125	102	126	97	127	97	128	*	133	*	133	*	135	*	135	*	135	*					
5796C			104	104	105	96	107	95	106	94	105	*	109	*	113	*	111	*	113	*	111	*					
5797C			104	109	104	103	105	101	103	99	103	*	109	*	111	*	112	*	111	*	107	*					
5798C	I	11	112	123	112	96	113	105	113	104	114	*	118	*	126	*	126	*	126	*	125	*					
5799C			120	115	120	104	120	102	121	102	120	*	122	*	130	*	130	*	139	*	138	*					
5800C			117	116	119	104	120	101	122	101	121	*	125	*	135	*	135	*	140	*	141	*					
5801C	II	21	116	123	116	109	116	106	114	104	116	*	120	*	121	*	121	*	124	*	124	*					
5802C			110	104	110	101	109	87	109	95	110	*	110	*	114	*	113	*	114	*	111	*					
5803C			110	118	110	94	110	98	108	96	108	*	112	*	113	*	110	*	114	*	115	*					
5804C	V	51	110	103	110	99	111	99	110	96	108	*	112	*	113	*	114	*	112	*	115	*					
5805C			113	121	111	98	110	99	111	100	111	*	118	*	119	*	120	*	113	*	115	*					
5806C			107	121	109	95	108	103	106	102	107	*	107	*	103	*	105	*	101	*	98	*					
5807C	I	18	101	114	101	93	103	95	102	93	104	*	108	*	108	*	111	*	112	*	111	*					
5808C			117	117	119	108	118	*	121	*	122	*	129	*	139	*	141	*	143	*	142	*					
5809C			110	114	107	95	108	*	109	*	111	*	115	*	117	*	121	*	121	*	120	*					
5810C	II	24**	106	117	106	92	106	94	103	94	105	*	109	*	107	*	104	*	99	*	100	*					
5811C			105	107	105	90	107	92	103	92	102	*	102	*	109	*	104	*	96	*	94	*					
5812C			115	111	113	95	113	106	114	104	115	*	117	*	121	*	118	*	118	*	124	*					
5813C	I	13	107	112	108	97	109	109	107	107	109	*	113	*	112	*	105	*	122	*	123	*					
5814C			99	126	98	90	106	100	100	99	102	*	100	*	89	*	94	*	85	*	93	*					
5815C			101	105	101	93	102	102	100	100	101	*	102	*	97	*	93	*	101	*	120	*					
5816C	IV	41**	120	110	120	116	120	105	120	103	118	*	123	*	129	*	124	*	122	*	120	*					
5817C			109	109	109	119	110	101	108	100	109	*	113	*	114	*	111	*	109	*	114	*					
5818C			112	116	111	93	112	107	111	105	113	*	113	*	115	*	109	*	122	*	119	*					
5819C	I	19A	115	124	113	113	113	113	115	111	113	*	115	*	121	*	120	*	120	*	119	*					
5820C			121	118	120	116	120	105	125	100	127	*	132	*	132	*	131	*	135	*	135	*					
5821C			122	121	117	103	118	106	121	101	123	*	128	*	132	*	130	*	132	*	130	*					
5822C	I	15	105	115	104	101	106	*	110	*	112	*	114	*	118	*	117	*	115	*	116	*					
5823C			102	116	102	102	101	*	103	*	104	*	106	*	116	*	115	*	116	*	119	*					
5824C			105	117	107	100	107	*	107	*	109	*	111	*	117	*	114	*	130	*	130	*					
5825C	I	19C	110	116	112	108	113	*	113	*	113	*	113	*	123	*	123	*	124	*	125	*					
5826C			112	110	113	102	113	*	112	*	112	*	114	*	124	*	124	*	129	*	124	*					
5827C			112	115	112	97	112	*	111	*	113	*	113	*	119	*	119	*	140	*	138	*					
5828C	I	11	110	112	108	96	109	*	112	*	111	*	116	*	120	*	115	*	112	*	114	*					
5829C			107	106	105	87	105	*	107	*	107	*	111	*	121	*	119	*	130	*	130	*					
5830C			107	115	105	95	106	*	106	*	107	*	111	*	118	*	117	*	123	*	118	*					
5831C	I	19A	109	120	110	89	112	*	109	*	111	*	115	*	113	*	108	*	113	*	115	*					
5832C			108	118	108	92	108	*	107	*	109	*	109	*	129	*	122	*	128	*	127	*					
5833C			118	123	118	90	119	*	119	*	120	*	125	*	115	*	109	*	114	*	116	*					
5834C	IV	43A*	117	127	115	114	114	*	115	*	116	*	116	*	120	*	112	*	115	*	117	*					
5835C			119	125	122	105	124	*	118	*	120	*	120	*	124	*	124	*	124	*	122	*					
5836C			118	100	117	102	118	*	108	*	106	*	108	*	114	*	112	*	110	*	114	*					
5837C	I	18	108	108	111	84	110	*	108	*	109	*	111	*	119	*	115	*	122	*	124	*					
5838C			114	112	114	100	115	*	118	*	120	*	122	*	137	*	135	*	150	*	153	*					
5839C			107	116	111	99	112	*	106	*	107	*	105	*	109	*	105	*	111	*	111	*					
5840C	I	15	98	105	98	85	99	*	101	*	102	*	102	*	112	*	111	*	123	*	123	*					
5841C			104	97	108	79	110	*	108	*	108	*	108	*	117	*	113	*	124	*	122	*					
5842C			97	103	97	80	99	*	97	*	99	*	101	*	109	*	106	*	110	*	113	*					
5843C	III	33†	105	108	105	93	106	*	107	*	108	*	110	*	112	*	108	*	122	*	125	*					
5844C			107	109	112	87	112	*	111	*	111	*	115	*	134	*	133	*	146	*	148	*					
5845C			113	113	113	85	113	*	117	*	119	*	123	*	140	*	135	*	164	*	140	*					
5846C	IV	43*	114	125	116	110	117	101	117	100	119	*	124	*	131	*	129	*	129	*	129	*					
5847C			96	122	96	92	98	96	92	96	92	*	96	*	92	*	90	*	86	*	88	*					
5848C			99	118	99	88	101	*	95	*	95	*	95	*	87	*	84	*	84	*	89	*					

(Continued)

\* Cements 43 and 43A made at same plant.

\*\* Cements 14, 24, and 41 made at same plant.

† Cements 25 and 33 made from same major raw materials.

\* End of specimen too rough to obtain satisfactory reading.

(Sheet 7)

(Revised May 1976)

Table 1-LTS (Continued)

Section 17

(Installed at Treat Island in July 1955)

Specimen No.	Cement Type	Pro-gram No.	1965-1974 Readings															
			1237		1367		1523		1708		1862		2015		2184		2341	
			Cycles		Cycles		Cycles		Cycles		Cycles		Cycles		Cycles		Cycles	
			1965	1966	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
5849C	I	16	106	110	110	96	110	†	106	†	108	†	110	†	113	†	109	†
5850C			115	120	117	105	117	†	116	†	117	†	121	†	123	†	124	†
5851C			107	126	107	103	107	†	105	†	104	†	106	†	112	†	108	†
5852C	I	13	109	130	107	102	108	†	106	†	108	†	108	†	112	†	110	†
5853C			109	123	109	88	108	†	109	†	111	†	113	†	116	†	117	†
5854C			108	128	108	91	107	†	109	†	109	†	109	†	118	†	120	†
5855C	III	31††	106	128	107	87	107	†	108	†	110	†	112	†	134	†	152	†
5856C			100	117	103	83	104	†	107	†	109	†	109	†	121	†	119	†
5857C			108	109	110	83	110	†	117	†	117	†	122	†	140	†	163	†
5858C	II	24**	115	111	113	90	112	95	114	94	115	†	115	†	121	†	115	†
5859C			113	116	113	98	113	100	111	96	113	†	113	†	117	†	117	†
5860C			89	111	86	90	84	101	80	97	80	†	84	†	77	†	69	†
5861C	I	14**	103	116	102	100	102	99	100	98	102	†	102	†	102	†	90	†
5862C			108	111	108	101	107	94	108	92	108	†	108	†	117	†	115	†
5863C			109	114	109	108	109	98	108	96	110	†	108	†	112	†	110	†
5864C	II	23	107	116	107	106	108	†	105	†	107	†	105	†	107	†	99	†
5865C			97	116	97	96	97	†	93	†	91	†	93	†	93	†	85	†
5866C			99	114	97	97	97	†	95	†	93	†	95	†	97	†	89	†
5867C	II	21	109	129	109	112	108	100	105	100	103	†	103	†	108	†	126	†
5868C			109	121	109	106	108	112	106	108	108	†	106	†	110	†	106	†
5869C			113	117	113	102	112	112	113	109	113	†	109	†	†	†	†	†
5870C	I	19B	110	114	109	96	109	108	109	105	110	†	107	†	†	†	102	†
5871C			109	111	109	90	109	†	107	†	109	†	109	†	†	†	101	†
5872C			101	117	98	94	99	†	96	†	98	†	98	†	94	†	90	†
5873C	I	12††	90	111	88	93	88	†	86	†	86	†	88	†	84	†	81	†
5874C			100	109	100	79	100	†	99	†	100	†	102	†	110	†	105	†
5875C			112	122	113	87	112	†	113	†	113	†	117	†	122	†	122	†
5876C	V	51	109	126	119	96	119	†	117	†	119	†	124	†	124	†	149	†
5877C			102	122	101	103	99	111	95	107	93	†	95	†	92	†	95	†
5878C			116	131	116	112	115	112	114	109	116	†	118	†	122	†	120	†
5879C	IV	41**	114	122	112	109	112	113	112	109	114	†	116	†	117	†	117	†
5880C			112	124	114	104	113	117	111	114	113	†	113	†	115	†	112	†
5881C			106	116	107	100	107	109	103	105	105	†	105	†	107	†	103	†
5882C	I	17	106	115	108	90	106	103	106	101	104	†	104	†	116	†	113	†
5883C			110	114	108	91	107	†	109	†	110	†	110	†	118	†	115	†
5884C			109	114	108	92	108	†	110	†	112	†	114	†	121	†	119	†
5885C	II	25†	111	110	112	104	110	†	108	†	108	†	112	†	112	†	109	†
5886C			111	119	112	104	111	107	109	102	111	†	113	†	109	†	113	†
5887C			119	127	120	108	118	103	120	100	120	†	122	†	131	†	125	†
5888C	II	22††	118	112	118	109	117	103	117	99	119	†	121	†	125	†	122	†
5889C			108	123	110	112	110	109	108	104	108	†	112	†	112	†	108	†
5890C			126	115	125	116	123	†	123	†	125	†	127	†	131	†	127	†

\*\* Cements 14, 24, and 41 made at same plant.

† Cements 25 and 33 made from same major raw materials.

†† Cements 12, 22, and 31 made at same plant.

‡ End of specimen too rough to obtain satisfactory reading.

(Sheet 8)

(Revised August 1977)

Table 1-LTS (Continued)

Section 17

(Installed at Treat Island in July 1955)

Specimen No.	Cement		2729		2875	2952
	Type	Pro-gram No.	Cycles 1975		Cycles 1976	Cycles 1977
			%E	%V <sup>2</sup>	%E	%E
5693C	IV	43A*	125	†	137	Failed
5694C			121	†	121	135
5695C			105	†	123	95
5696C	II	21	102	†	113	97
5697C			112	†	136	112
5698C			100	†	100	117
5699C	IV	41**	110	†	107	108
5700C			111	†	108	128
5701C			106	†	107	107
5702C	I	16	97	†	106	122
5703C			96	†	101	102
5704C			112	†	112	117
5705C	V	51	98	†	121	121
5706C			95	†	100	68
5707C			69	†	88	88
5708C	I	13	93	†	99	91
5709C			101	†	102	99
5710C			114	†	114	125
5711C	I	11	126	†	128	139
5712C			127	†	130	136
5713C			132	†	132	147
5714C	II	23	135	†	137	139
5715C			128	†	129	136
5716C			129	†	132	132
5717C	II	25†	136	†	134	150
5718C			130	†	132	143
5719C			126	†	126	133
5720C	I	19B	125	†	127	133
5721C			130	†	137	138
5722C			127	†	128	135
5723C	I	19C	136	†	137	137
5724C			139	†	139	140
5725C			130	†	130	133
5726C	I	12††	132	†	137	137
5727C			131	†	132	130
5728C			133	†	133	130
5729C	I	17	128	†	128	130
5730C			130	†	131	130
5731C			118	†	122	Failed
5732C	III	31††	144	†	Failed	
5733C			154	†	154	Failed
5734C			156	†	156	Failed
5735C	I	15	131	†	133	Failed
5736C			106	†	110	Failed
5737C			110	†	125	110
5738C	II	22††	117	†	118	129
5739C			132	†	134	132
5740C			136	†	136	Failed

(Continued)

(Sheet 9)

- \* Cements 43 and 43A made at same plant.
- \*\* Cements 14, 24, and 41 made at same plant.
- † Cements 25 and 33 made from some major raw materials.
- †† Cements 12, 22, and 31 made at same plant.
- ‡ End of specimen too rough to obtain satisfactory reading. %V<sup>2</sup> data discontinued.

(Revised August 1977)

Table 1-LTS (Continued)

Section 17

(Installed at Treat Island in July 1955)

Specimen No.	Cement		1975- Readings			
	Type	Pro-gram No.	2729	2875	2952	
			Cycles 1975	Cycles 1976	Cycles 1977	
			%E	%E	%E	
5741C	III	33+	147	150	Failed	
5743C			139	113	140	
5744C	I	14**	115	114	144	
5745C			119	121	119	
5746C			Missing			
5747C	II	24**	124	123	124	
5748C			118	119	134	
5749C			113	117	117	
5750C	I	19A	129	130	135	
5751C			127	132	132	
5752C			131	133	133	
5753C	I	18	107	Failed		
5754C			115	Failed		
5755C			134	Failed		
5756C	IV	43*	133	Failed		
5757C			123	123	Failed	
5758C			128	128	130	
5759C	II	22++	112	112	127	
5760C			131	133	141	
5761C			134	139	135	
5762C	IV	43*	120	122	120	
5763C			132	133	132	
5764C			125	125	125	
5765C	II	25+	129	130	128	
5766C			124	126	Failed	
5767C			124	124	126	
5768C	II	23	118	120	119	
5769C			119	120	119	
5770C			133	133	122	
5771C	I	17	116	116	116	
5772C			126	124	120	
5773C			110	112	112	
5774C	IV	43A*	130	128	160	
5775C			133	134	137	
5776C			142	141	142	
5777C	I	16	124	132	133	
5778C			119	120	115	
5779C			130	124	123	
5780C	III	31++	136	Failed		
5781C			163	Failed		
5782C			160	Failed		
5783C	III	33+	157	Failed		
5784C			155	Failed		
5785C			156	Failed		
5786C	I	12++	107	110	110	
5787C			111	115	117	
5788C			117	117	122	
5789C	I	19B	129	130	112	
5790C			130	125	133	
5791C			119	119	114	
5792C	I	19C	131	130	126	
5793C			101	103	103	
5794C			128	132	133	

(Continued)

\* Cements 43 and 43A made at same plant.

\*\* Cements 14, 24, and 41 made at same plant.

+ Cements 25 and 33 made from same major raw materials.

++ Cements 12, 22, and 31 made at same plant.

\* End of specimen too rough to obtain satisfactory reading. %v<sup>2</sup> data discontinued.

(Sheet 10)

(Revised August 1977)

Table 1-LTS (Continued)

Section 17

(Installed at Treat Island in July 1955)

Specimen No.	Type	Cement		1975- Readings			
		Pro-gram No.	2729		2875	2952	
			Cycles	$\bar{x}$	Cycles	Cycles	
			1975	$\bar{x}$	1976	1977	
5795C	I	14**	135	†	130	128	
5796C			112	†	113	155	
5797C			107	†	106	107	
5798C	I	11	125	†	119	119	
5799C			142	†	142	142	
5800C			141	†	146	130	
5801C	II	21	124	†	122	124	
5802C			112	†	113	115	
5803C			116	†	116	116	
5804C	V	51	116	†	116	120	
5805C			115	†	115	Failed	
5806C			99	†	103	108	
5807C	I	18	112	†	115	116	
5808C			142	†	152	147	
5809C			120	†	123	111	
5810C	II	24**	102	†	108	107	
5811C			95	†	104	103	
5812C			125	†	126	128	
5813C	I	13	123	†	116	114	
5814C			94	†	102	102	
5815C			122	†	124	125	
5816C	IV	41**	125	†	126	127	
5817C			115	†	116	117	
5818C			120	†	117	119	
5819C	I	19A	119	†	117	118	
5820C			135	†	137	137	
5821C			130	†	129	Failed	
5822C	I	15	117	†	115	Failed	
5823C			119	†	125	97	
5824C			131	†	136	131	
5825C	I	19C	130	†	135	130	
5826C			126	†	126	129	
5827C			138	†	143	143	
5828C	I	11	116	†	114	113	
5829C			130	†	137	130	
5830C			120	†	123	124	
5831C	I	19A	117	†	121	Failed	
5832C			129	†	129	130	
5833C			120	†	139	128	
5834C	IV	43A*	119	†	122	Failed	
5835C			122	†	127	Failed	
5836C			118	†	126	Failed	
5837C	I	18	124	†	130	Failed	
5838C			153	†	166	155	
5839C			115	†	121	132	
5840C	I	15	124	†	Failed		
5841C			122	†	Failed		
5842C			114	†	Failed		
5843C	III	33†	125	†	Failed		
5844C			148	†	Failed		
5845C			141	†	Failed		
5846C	IV	43*	131	†	Failed		
5847C			90	†	Failed		
5848C			91	†	Failed		

(Continued)

\* Cements 43 and 43A made at same plant.

\*\* Cements 14, 24, and 41 made at same plant.

† Cements 25 and 33 made from same major raw materials.

‡ End of specimen too rough to obtain satisfactory reading.  $\bar{x}$  data discontinued.

(Sheet 11)

(Revised August 1977)

Table 1-LTS (Continued)

Section 17

(Installed at Treat Island in July 1955)

Specimen No.	Cement Type	Pro-gram No.	1975- Readings			
			2729		2875	
			Cycles		Cycles	
			1975		1977	
			%E	%V <sup>2</sup>	%E	%E
5849C	I	16	119	‡	124	118
5850C			127	‡	127	129
5851C			114	‡	115	114
5852C	I	13	106	‡	103	101
5853C			119	‡	120	120
5854C			123	‡	131	134
5855C	III	31++	155	‡	166	158
5856C			123	‡	Failed	
5857C			162	‡	178	Failed
5858C	II	24**	127	‡	132	132
5859C			121	‡	122	Failed
5860C			70	‡	62	128
5861C	I	14**	96	‡	91	97
5862C			116	‡	115	117
5863C			115	‡	118	105
5864C	II	23	114	‡	117	114
5865C			77	‡	79	77
5866C			97	‡	102	Failed
5867C	II	21	108	‡	110	112
5868C			112	‡	116	118
5869C			‡	‡	Failed	
5870C	I	19B	114	‡	117	124
5871C			120	‡	125	127
5872C			99	‡	107	109
5873C	I	12++	87	‡	92	92
5874C			109	‡	112	112
5875C			127	‡	123	124
5876C	V	51	125	‡	127	127
5877C			88	‡	95	Failed
5878C			123	‡	126	128
5879C	IV	41**	121	‡	124	125
5880C			113	‡	114	114
5881C			106	‡	115	135
5882C	I	17	114	‡	112	112
5883C			125	‡	123	123
5884C			123	‡	124	125
5885C	II	25+	114	‡	114	146
5886C			115	‡	113	119
5887C			134	‡	135	136
5888C	II	22++	132	‡	135	134
5889C			117	‡	120	152
5890C			130	‡	133	158

\*\* Cements 14, 24, and 41 made at same plant.

† Cements 25 and 33 made from same major raw materials.

†† Cements 12, 22, and 31 made at same plant.

‡ End of specimen too rough to obtain satisfactory reading.  $\%V^2$  data discontinued.

(Revised Sept 1970)

Table 2-LTS

Section 17

## Record of Testing of Concrete Beams, Longtime Study, WES

St. Augustine Exposure

1955- (Installed Summer 1955)

		1955-1960 Readings																							
Specimen No.	Cement Type	LTS No.	1955			1956		1958		1960		1962*		1964*		1966*		1968*		1970*					
			Pulse Veloc ft/s	$\%V^2$		ft/s	$\%V^2$	ft/s	$\%V^2$	ft/s	$\%V^2$	ft/s	$\%V^2$	ft/s	$\%V^2$	ft/s	$\%V^2$	ft/s	$\%V^2$	ft/s	$\%V^2$	ft/s	$\%V^2$		
5891D	IV	43A**	100	15,255	100	105	108	110	108	Lost															
5892D			100	15,575	100	106	100	108	101	121	110														
5893D			100	15,220	100	106	109	111	105	119	104														
5972D	IV	43A**	100	15,290	100	106	110	108	113	118	109														
5973D			100	15,290	100	109	98	112	111	121	108														
5974D			100	14,715	100	117	122	122	122	133	119														
6032D	IV	43A**	100	15,540	100	108	--	112	103	122	106														
6033D			100	16,105	100	100	--	97	97	106	100														
6034D			100	16,065	100	100	--	100	100	109	101														
5894D	II	21	100	15,360	100	110	109	115	109	124	110														
5895D			100	15,470	100	104	105	107	107	111	105														
5896D			100	15,910	100	102	100	105	100	105	97														
5999D	II	21	100	15,800	100	97	103	99	101	108	106														
6000D			100	15,615	100	101	106	103	101	109	104														
6001D			100	15,950	100	99	101	98	100	105	100														
6065D	II	21	100	16,220	100	99	--	104	96	114	98														
6066D			100	16,105	100	102	--	92	95	100	99														
6067D			100	15,835	100	102	--	108	97	115	101														
5897D	IV	41†	100	15,725	100	102	98	105	99	113	99														
5898D			100	15,800	100	105	99	104	99	118	100														
5899D			100	15,875	100	103	100	107	100	113	99														
6014D	IV	41†	100	15,360	100	112	--	116	106	121	102														
6015D			100	15,505	100	107	--	110	105	114	105														
6016D			100	15,650	100	103	--	100	103	106	101														
6077D	IV	41†	100	15,950	100	98	--	103	95	111	101														
6078D			100	15,725	100	104	--	108	97	118	91														
6079D			100	15,725	100	105	--	110	98	119	102														
5900D	I	16	100	15,910	100	96	98	99	101	99	102														
5901D			100	15,985	100	95	98	98	99	104	99														
5902D			100	15,910	100	96	100	98	101	102	102														
5975D	I	16	100	15,150	100	107	106	116	113	128	109														
5976D			100	15,255	100	108	108	111	109	120	107														
5977D			100	15,505	100	107	108	111	109	120	103														
6047D	I	16	100	16,460	100	100	--	97	93	103	93														
6048D			100	16,260	100	101	--	99	94	108	98														
6049D			100	15,985	100	105	--	105	99	111	101														
5903D	V	51	100	15,800	100	101	101	103	103	111	101														
5904D			100	15,800	100	102	102	105	105	111	103														
5905D			100	15,835	100	102	101	105	105	112	98														
6002D	V	51	100	15,985	100	100	102	101	97	107	103														
6003D			100	15,835	100	102	97	103	103	109	100														
6004D			100	15,615	100	104	105	106	104	113	102														
6074D	V	51	100	15,760	100	105	--	110	104	120	106														
6075D			100	15,725	100	111	--	112	105	123	107														
6076D			100	15,835	100	108	--	108	104	119	105														
5906D	I	13	100	15,950	100	100	101	103	107	110	99														
5907D			100	15,910	100	102	100	103	108	108	100														
5908D			100	15,685	100	104	102	109	109	117	105														
6011D	I	13	100	15,910	100	102	--	103	99	110	98														
6012D			100	15,760	100	104	--	104	103	111	103														
6013D			100	15,505	100	104	--	106	103	114	105														

(Continued)

-- Dashed lines in " $\%V^2$ " column in 1956 indicate that pulse velocity readings were not taken that year due to breakdown of electronic equipment.

\* The information obtained at the July 1964 inspection of these specimens indicated the specimens could not be identified. The loss of identification is believed to have taken place in April 1962, consequently data developed subsequent to that date, previously reported, have been deleted.

\*\* Cements 43 and 43A made at same plant.

† Cements 14, 24, and 41 made at same plant.

(Sheet 1)

(Revised Sept 1970)

Table 2-LTS (Continued)

Section 17

1955-1960 Readings																					
Specimen No.	Cement Type	LTS No.	1955			1956		1958		1960		1962*		1964*		1966*		1968*		1970*	
			$\bar{V}$	Pulse Veloc fps	$\bar{V}^2$	$\bar{V}$	$\bar{V}^2$	$\bar{V}$	$\bar{V}^2$	$\bar{V}$	$\bar{V}^2$	$\bar{V}$	$\bar{V}^2$	$\bar{V}$	$\bar{V}^2$	$\bar{V}$	$\bar{V}^2$	$\bar{V}$	$\bar{V}^2$	$\bar{V}$	$\bar{V}^2$
6050D	I	13	100	15,985	100	100	---	98	96	104	100										
6051D			100	16,065	100	99	---	96	95	105	100										
6052D			100	15,950	100	103	---	94	94	101	101										
5909D	I	11	100	15,430	100	108	105	112	108	117	107										
5910D			100	15,615	100	108	104	112	108	119	103										
5911D			100	15,290	100	106	106	111	110	120	107										
5996D	I	11	100	15,910	100	95	100	104	98	104	99										
5997D			100	16,300	100	102	98	100	97	110	95										
5998D			100	15,910	100	99	100	99	101	107	99										
6026D	I	11	100	16,260	100	102	---	97	96	104	98										
6027D			100	16,105	100	100	---	102	98	109	98										
6028D			100	16,065	100	101	---	100	96	109	99										
5912D	II	23	100	15,540	100	105	105	109	109	125	102										
5913D			100	15,360	100	107	106	110	110	110	104										
5914D			100	15,540	100	105	104	108	106	117	104										
5966D	II	23	100	16,025	100	96	105	96	106	105	102										
5967D			100	15,985	100	96	106	97	109	103	103										
5968D			100	16,105	100	94	101	95	107	102	93										
6062D	II	23	100	16,065	100	100	---	94	95	104	101										
6063D			100	16,420	100	100	---	109	90	116	97										
6064D			100	16,220	100	98	---	90	95	103	94										
5915D	II	25++	100	15,290	100	108	111	113	111	122	110										
5916D			100	15,150	100	111	107	113	110	119	109										
5917D			100	15,185	100	110	109	113	108	123	108										
5963D	II	25++	100	15,910	100	99	105	101	105	109	99										
5964D			100	15,985	100	101	103	102	106	109	100										
5965D			100	16,065	100	97	107	98	110	106	100										
6083D	II	25++	100	16,065	100	102	---	104	98	112	100										
6084D			100	16,260	100	99	---	102	98	113	97										
6085D			100	16,065	100	103	---	105	96	114	102										
5918D	I	19B	100	15,540	100	103	105	108	104	114	104										
5919D			100	15,540	100	104	105	105	105	109	102										
5920D			100	15,360	100	105	108	107	106	115	104										
5987D	I	19B	100	15,115	100	105	110	109	109	118	105										
5988D			100	15,150	100	105	108	109	108	117	108										
5989D			100	15,115	100	104	111	107	108	117	109										
6068D	I	19B	100	15,760	100	101	---	100	99	108	101										
6069D			100	15,615	100	101	---	101	98	100	102										
6070D			100	15,800	100	102	---	110	96	124	102										
5921D	I	19C	100	15,725	100	103	103	105	102	111	99										
5922D			100	15,910	100	106	101	108	100	118	103										
5923D			100	15,835	100	102	102	104	104	112	99										
5990D	I	19C	100	15,685	100	103	101	107	103	115	104										
5991D			100	15,800	100	98	101	101	99	108	101										
5992D			100	15,950	100	95	99	97	99	102	99										
6023D	I	19C	100	15,615	100	102	---	103	100	108	100										
6024D			100	15,540	100	103	---	105	101	110	99										
6025D			100	15,505	100	102	---	102	99	102	98										
5924D	I	12*	100	15,650	100	112	107	115	107	125	106										
5925D			100	15,875	100	105	103	108	108	116	99										
5926D			100	15,540	100	109	106	112	112	120	98										
5984D	I	12*	100	15,185	100	106	111	110	112	119	110										
5985D			100	15,685	100	105	107	109	109	118	102										
5986D			100	15,360	100	107	89	110	113	120	105										
6071D	I	12*	100	16,105	100	102	---	107	96	117	101										
6072D			100	16,625	100	99	---	107	93	114	96										
6073D			100	16,420	100	103	---	97	93	108	99										

(Continued)

-- Dashed lines in " $\bar{V}^2$ " column in 1956 indicate that pulse velocity readings were not taken that year due to breakdown of electronic equipment.

\* The information obtained at the July 1964 inspection of these specimens indicated the specimens could not be identified. The loss of identification is believed to have taken place in April 1962, consequently data developed subsequent to that date, previously reported, have been deleted.

++ Cements 25 and 33 made from same major raw materials.

\* Cements 12, 22, and 31 made at same plant.

(Sheet 2)

(Revised Sept 1970)

Table 2-LTS (Continued)

Section 17

1955-1960 Readings																					
Specimen No.	Cement Type	LTS No.	1955		1956		1958		1960		1962*		1964*		1966*		1968*		1970*		
			Pulse Veloc																		
			ft	fps	ft <sup>2</sup>	ft	ft <sup>2</sup>	ft	ft <sup>2</sup>	ft	ft <sup>2</sup>	ft	ft <sup>2</sup>	ft	ft <sup>2</sup>	ft	ft <sup>2</sup>	ft	ft <sup>2</sup>	ft	ft <sup>2</sup>
5927D	I	17	100	15,505	100	103	104	105	107	114	105										
5928D			100	15,085	100	108	104	110	111	116	106										
5929D			100	15,185	100	108	103	109	108	108	103										
5969D	I	17	100	16,220	100	96	96	98	98	104	96										
5970D			100	16,140	100	95	99	97	103	102	97										
5971D			100	16,065	100	95	100	96	100	102	96										
6080D	I	17	100	15,985	100	102	--	103	94	113	100										
6081D			100	16,260	100	101	--	103	94	113	97										
6082D			100	16,065	100	98	--	100	97	110	100										
5930D	III	31*	100	15,150	100	105	105	105	104	108	100										
5931D			100	15,150	100	100	105	100	105	122	100										
5932D			100	15,430	100	100	96	99	100	114	95										
5978D	III	31*	100	15,220	100	105	105	109	106	124	104										
5979D			100	15,290	100	106	99	109	103	116	103										
5980D			100	15,185	100	102	105	104	107	109	100										
6053D	III	31*	100	15,760	100	99	--	96	91	101	97										
6054D			100	15,760	100	101	--	104	89	102	95										
6055D			100	15,760	100	99	--	107	88	115	104										
5933D	I	15	100	15,615	100	101	99	99	99	103	99										
5934D			100	15,575	100	103	94	101	101	107	101										
5935D			100	15,835	100	101	99	99	99	107	97										
6020D	I	15	100	16,300	100	95	--	95	92	93	97										
6021D			100	16,140	100	98	--	97	96	103	95										
6022D			100	16,220	100	97	--	Broken in handling													
6038D	I	15	100	16,300	100	97	--	96	89	102	96										
6039D			100	16,340	100	95	--	94	89	101	95										
6040D			100	16,220	100	98	--	94	93	102	95										
5936D	II	22*	100	15,430	100	104	106	104	108	109	98										
5937D			100	15,220	100	106	107	106	111	117	102										
5938D			100	15,650	100	104	103	105	108	109	97										
5957D	II	22*	100	16,220	100	100	99	102	103	102	100										
5958D			100	15,760	100	103	102	105	106	113	104										
5959D			100	15,835	100	104	102	108	108	117	104										
6086D	II	22*	100	15,985	100	102	--	106	96	117	104										
6087D			100	15,760	100	109	--	109	102	120	103										
6088D			100	15,835	100	106	--	110	98	119	102										
5939D	III	33††	100	15,650	100	101	101	102	111	105	97										
5940D			100	15,650	100	102	99	102	106	115	97										
5941D			100	15,615	100	101	101	101	105	112	95										
5981D	III	33††	100	15,650	100	102	99	104	99	110	100										
5982D			100	15,255	100	102	104	103	106	112	100										
5983D			100	15,185	100	103	105	105	105	112	101										
6041D	III	33††	100	15,835	100	99	--	95	97	102	97										
6042D			100	15,725	100	98	--	105	97	104	94										
6043D			100	15,950	100	100	--	100	95	108	93										
5942D	I	14†	100	16,065	100	97	101	97	101	98	102										
5943D			100	15,985	100	104	100	105	106	114	100										
5944D			100	15,650	100	106	106	108	106	119	103										
5993D	I	14†	100	16,300	100	96	97	99	101	107	96										
5994D			100	16,220	100	96	101	98	100	105	99										
5995D			100	16,260	100	96	102	98	97	107	98										
6059D	I	14†	100	16,420	100	98	--	107	88	115	94										
6060D			100	16,260	100	98	--	88	90	97	94										
6061D			100	16,180	100	101	--	107	91	112	94										
5945D	II	24†	100	15,725	100	103	103	105	106	114	98										
5946D			100	15,575	100	105	101	108	106	116	101										
5947D			100	15,360	100	110	108	112	113	119	103										

(Continued)

-- Dashed lines in " $\bar{V}^2$ " column in 1956 indicate that pulse velocity readings were not taken that year due to breakdown of electronic equipment.

\* The information obtained at the July 1964 inspection of these specimens indicated the specimens could not be identified. The loss of identification is believed to have taken place in April 1962, consequently data developed subsequent to that date, previously reported, have been deleted.

† Cements 14, 24, and 41 made at same plant.

†† Cements 25 and 33 made from same major raw materials.

\* Cements 12, 22, and 31 made at same plant.

(Sheet 3)

(Revised Sept 1970)

Table 2-LTS (Concluded)

Section 17

1955-1960 Readings																					
Specimen No.	Cement Type	LTS No.	1955		1956		1958		1960		1962*		1964*		1966*		1968*		1970*		
			Pulse Veloc fps	$\frac{V}{E}$	$\frac{V^2}{E^2}$	$\frac{V}{E}$	$\frac{V^2}{E^2}$	$\frac{V}{E}$	$\frac{V^2}{E^2}$	$\frac{V}{E}$	$\frac{V^2}{E^2}$	$\frac{V}{E}$	$\frac{V^2}{E^2}$	$\frac{V}{E}$	$\frac{V^2}{E^2}$	$\frac{V}{E}$	$\frac{V^2}{E^2}$	$\frac{V}{E}$	$\frac{V^2}{E^2}$		
6056D	II	24†	100	16,300	100	102	---	110	90	121	93										
6057D			100	15,950	100	102	---	96	89	106	98										
6058D			100	15,835	100	102	---	108	92	108	93										
6008D	II	24†	100	15,395	100	102	---	105	100	113	100										
6009D			100	15,505	100	103	---	106	97	113	97										
6010D			100	15,430	100	107	---	108	100	118	101										
5948D	I	19A	100	15,085	100	109	111	113	117	121	107										
5949D			100	15,115	100	107	108	109	118	117	104										
5950D			100	15,115	100	107	110	109	117	120	105										
6029D	I	19A	100	15,725	100	106	---	106	104	116	104										
6030D			100	15,650	100	105	---	107	102	Bkn in halg											
6031D			100	15,615	100	106	---	112	103	120	104										
6017D	I	19A	100	15,085	100	105	---	109	109	113	106										
6018D			100	14,950	100	113	---	116	112	121	108										
6019D			100	15,185	100	104	---	108	105	117	108										
5951D	I	18	100	15,950	100	100	98	101	101	106	99										
5952D			100	16,005	100	101	98	102	100	114	97										
5953D			100	15,575	100	106	107	107	114	112	103										
6005D	I	18	100	15,800	100	103	98	106	101	113	102										
6006D			100	15,470	100	106	104	108	104	119	105										
6007D			100	15,835	100	103	100	105	101	112	100										
6035D	I	18	100	16,340	100	100	---	97	93	104	99										
6036D			100	15,985	100	100	---	99	98	107	100										
6037D			100	16,025	100	101	---	104	98	111	100										
5954D	IV	43**	100	15,360	100	106	102	109	113	118	108										
5955D			100	15,650	100	101	96	102	108	112	100										
5956D			100	15,615	100	101	103	102	105	109	99										
5960D	IV	43**	100	15,255	100	113	111	118	114	126	115										
5961D			100	15,325	100	116	114	121	115	127	113										
5962D			100	15,290	100	116	111	121	118	130	113										
6044D	IV	43**	100	15,220	100	104	---	116	100	126	104										
6045D			100	15,615	100	103	---	109	99	120	98										
6046D			100	15,875	100	100	---	99	98	97	97										

-- Dashed lines in " $\frac{V^2}{E^2}$ " column in 1956 indicate that pulse velocity readings were not taken that year due to breakdown of electronic equipment.

\* The information obtained at the July 1964 inspection of these specimens indicated the specimens could not be identified. The loss of identification is believed to have taken place in April 1962, consequently data developed subsequent to that date, previously reported, have been deleted.

\*\* Cements 43 and 43A made at same plant.

† Cements 14, 24, and 41 made at same plant.

(Sheet 4)

(Issued August 1977)

Key to Section 18

Charles River Dam-Smelt Brook Local Protection Project  
New England Division

Aggregates: Coarse "A," natural gravel, Ossipee, N. H.

Fine "A," natural sand, Ossipee, N. H.

Coarse "B," crushed quarry and natural gravel,  
Marshfield sand and gravel.

Fine "B," natural sand, Marshfield sand and gravel.

Admixtures: Water Reducer "A," Pozzolith 122 N, Master Builders.

Water Reducer "B," WRDA, W. R. Grace

Air-entraining "A," MBVR, Master Builders.

Air-entraining "B," DAREX, W. R. Grace.

Cement: Atlantic type II, Hudson Valley, N. Y.

(Issued August 1977)

Section 18

Charles River Dam-Smelt Brook Local Protection Project

New England Division

In August 1976, 18 concrete beams (6 by 6 by 24 in.) were installed on the Treat Island exposure rock for the U. S. Army Engineer Division, CE, New England. These specimens represent three concrete mixes used for two construction jobs; Mixes 1 and 2 were used for the Charles River Dam, Boston, Mass., and Mix 3 was used for Smelt Brook Local Protection Project, Weymouth, Mass. Type II Portland cement was used in the three mixes. Mixes 1 and 2 contain coarse and fine aggregates "A" (1-1/2 in. maximum size), water reducer, and air-entraining admixture "A." Mix 3 contains coarse and fine aggregates "B" (3/4-in. maximum size), water reducer, and air-entraining admixtures "B." More mixture data are given in Table 1. Table 1-NED gives the exposure record of the installed beams.

(Issued August 1977)

Table 1

Charles River Dam-Smelt Brook Local Protection ProjectNew England Division

Formula Number	Charles River Dam, Boston-Charlestown, Mass.			Smelt Brook Local Protection, Weymouth, Mass.		
	Mix 1	Mix 1	Mix 2	Mix 2	Mix 3	Mix 3
Tag Identification Numbers*	7, 8, 9	10, 11, 12	13, 14, 15	16, 17, 18	1, 2, 3	4, 5, 6
N.E.D. nomenclature	-	-	-	-	2A, 2B, 2C	1A, 1B, 1C
Date of fabrication	10/6/75	10/7/75	10/17/75	10/22/75	9/5/75	8/14/75
Slump, in.	2.50	2.50	3.00	2.50	3.00	3.00
Air content, %	5.2	5.0	5.7	4.3	3.0	4.2
Concrete temperature, °F	62	62	75	66	78	72
Unit weight of fresh concrete, pcf	145.2	-	144.7	145.0	143.63	142.97
Compression cylinders	229-A, C, D	230-A, C, D	241-A, C, D	244-A, C, D	43-A, C, D	40-A, C, D
Compressive strength, psi						
7-day	3890	3820	3855	3960	2810	4310
28-day	4870	5095	4420	5375	3940	5440
28-day	4955	5180	4670	5375	4020	5360

\* Identification tag is attached to each specimen.

(Issued August 1977)

Section 18

Table 1-NED

Record of Testing of Concrete Specimens from Charles River Dam, and  
Smelt Brook Local Protection Project (Installed August 1976)

Exposure Rack, Row 3					
Beam No.	1976-			Readings	
	0 Cycles 1976		77 Cycles 1977		
	%E	Pulse Veloc fps	%V <sup>2</sup>	%E	%V <sup>2</sup>
1	100	16,000	100	100	98
2	100	16,130	100	106	97
3	100	16,000	100	107	98
4	100	17,240	100	113	88
5	100	17,700	100	108	89
6	100	17,240	100	115	95
7	100	16,130	100	107	91
8	100	16,260	100	106	97
9	100	15,750	100	105	105
10	100	16,130	100	116	97
11	100	16,530	100	112	91
12	100	16,000	100	111	95
13	100	15,750	100	108	97
14	100	15,875	100	105	97
15	100	15,750	100	107	98
16	100	15,875	100	105	98
17	100	16,130	100	99	95
18	100	16,260	100	107	95

Mt. Morris Dam\* Cores

In October 1949, 11 concrete cores (10 in. in diameter by 18 in. long) taken from concrete placed at Mt. Morris Dam, N. Y., between May and August 1949, were installed on the Treat Island exposure rack. The purpose of this installation was to determine the durability of these cores. The aggregates used consisted of crushed limestone and manufactured limestone sand; the cement was type II-A. Five of these cores were taken from the upstream face of the structure and represent exterior concrete of approximately 4.0-bags-per-cu-yd cement factor. The remaining six cores represent interior concrete of approximately 3.1-bags-per-cu-yd cement factor.

Table 1-MM lists these cores and gives their exposure record along with other pertinent information.

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\* See U. S. Army Engineer Waterways Experiment Station, CE, Aggregate Tests, Mount Morris Dam (Vicksburg, Miss., February 1948).

(Revised August 1977)

Table 1-MM

Section 22

## Record of Testing of Concrete Cores, Mount Morris Dam

1949- (Installed October 1949)

East Bay, Row 1 (N to S)

		1949-1958 Readings																	
Specimen No.	Water Cement Ratio (by wt)	Air %	0	161	250	351	436	547	692	859	1003	1074							
			Cycles	Cycles	Cycles	Cycles	Cycles	Cycles	Cycles	Cycles	Cycles	Cycles							
			1949	1950	1951	1952	Pulse	1954	1955	1956	1957	1958							
			Veloc	fps	ft/sec	ft/sec	ft/sec	ft/sec	ft/sec	ft/sec	ft/sec	ft/sec							
Exterior, Nominal 4-bag-per-cu-yd Cement Factor																			
Con-1-20(1)	0.49	4.1	100	109	109	114	118	16,855	100	119	96	117	98	127	90	125	92	125	103
Con-2-21(2)	0.49	4.1	100	104	112	114	114	16,305	100	116	90	118	100	124	92	122	96	122	99
Con-3-22(1)	0.49	4.1	100	110	114	118	119	16,665	100	123	92	125	107	129	94	129	98	132	105
Con-5-24(2)	0.49	4.1	100	113	115	121	118	16,485	100	125	96	123	100	129	90	126	96	120	100
Con-6-24A	0.49	4.1	100	108	113	117	117	16,855	100	121	96	122	105	128	94	125	92	132	100
Interior, Nominal 3-bag-per-cu-yd Cement Factor																			
Con-8-3A	0.59	4.6	100	112	114	115	118	16,485	100	120	102	121	105	126	100	128	100	130	107
Con-9-3B(1)	0.59	4.7	100	113	115	113	119	16,485	100	119	107	115	112	116	105	117	103	120	108
Con-11-7	0.61	4.3	100	106	108	113	112	15,790	100	117	100	116	107	121	96	110	98	112	104
Con-12-8(2)	0.59	3.3	100	107	110	114	115	15,955	100	120	100	121	104	126	98	124	102	127	104
Con-14-9B(2)	0.59	3.3	100	104	115	118	118	16,130	100	120	94	119	100	124	92	116	94	115	100
Con-15-10	0.62	4.2	100	103	111	113	114	15,625	100	117	102	96	98	102	92	97	92	104	96

Exposure Rack, Row 4 (W to E)

		1959-1968 Readings																2215				2400											
		1224				1295				1436				1525				1631				1766				1929		2059		2215		2400	
		Cycles				Cycles				Cycles				Cycles				Cycles				Cycles				Cycles		Cycles		Cycles		Cycles	
		1959				1960				1961				1962				1963				1964				1965		1966		1967		1968	
		£	¢	¢	¢	£	¢	¢	¢	£	¢	¢	¢	£	¢	¢	¢	£	¢	¢	¢	£	¢	¢	¢	£	¢	¢	¢	£	¢	¢	¢
Exterior, Nominal 4-bag-per-cu-yd Cement Factor																																	
Con-1-20(1)	0.49	4.1	132.	90	125	92	123	98	111	92	117	107	113	82	107	90	107	76	97	67	93	72											
Con-2-21(2)	0.49	4.1	131	91	134	97	125	104	123	90	122	102	117	94	113	100	109	94	98	85	108	85											
Con-3-22(1)	0.49	4.1	137	90	133	86	125	92	120	84	121	90	109	90	119	98	106	86	99	81	94	81											
Con-5-24(2)	0.49	4.1	126	90	130	92	126	90	134	77	116	98	119	92	129	100	124	77	106	72	104	78											
Con-6-24A	0.49	4.1	132	84	129	89	123	94	119	98	119	92	113	88	114	88	109	81	98	75	111	82											
Interior, Nominal 3-bag-per-cu-yd Cement Factor																																	
Con-8-3A	0.59	4.6	127	94	129	98	122	96	118	96	116	102	110	100	101	94	101	92	92	88	93	88											
Con-9-3B(1)	0.59	4.7	106	101	113	101	107	102	100	71	76	86	71	109	67	83	67	58	62	59	66	39											
Con-11-7	0.61	4.3	113	94	115	96	101	88	103	92	101	102	93	94	80	90	86	72	74	77	74	71											
Con-12-8(2)	0.59	3.3	122	92	125	92	112	96	111	104	115	104	106	98	105	96	100	79	83	88	91	88											
Con-14-9B(2)	0.59	3.3	109	83	106	92	98	96	95	77	91	102	124	92	109	82	127	69	112	68	107	68											
Con-15-10	0.62	4.2	98	89	92	89	87	89	86	79	77	92	68	89	60	78	61	--	Failed														

1969-1977 Readings

		1969-1977 Readings																																			
		2554				2707				2876				3033				3173				3309				3421				3570				3647			
		Cycles				Cycles				Cycles				Cycles				Cycles				Cycles				Cycles				Cycles							
		1969				1970				1971				1972				1973				1974				1975				1976				1977			
		$\frac{E}{V}$	$\frac{V}{V^2}$			$\frac{E}{V}$	$\frac{V}{V^2}$			$\frac{E}{V}$	$\frac{V}{V^2}$			$\frac{E}{V}$	$\frac{V}{V^2}$			$\frac{E}{V}$	$\frac{V}{V^2}$			$\frac{E}{V}$	$\frac{V}{V^2}$			$\frac{E}{V}$	$\frac{V}{V^2}$			$\frac{E}{V}$	$\frac{V}{V^2}$						
<u>Exterior, Nominal 4-bag-per-cu-yd Cement Factor</u>																																					
Con-1-20(1)	0.49	4.1	92	59	93	55	91	27	NR	26	Failed																										
Con-2-21(2)	0.49	4.1	108	81	105	69	105	29	Failed																												
Con-3-22(1)	0.49	4.1	93	69	NR	54	93	41	Failed																												
Con-5-24(2)	0.49	4.1	106	75	111	69	106	52	109	40	101	71	97	75	97	90	96	83	117	74																	
Con-6-24A	0.49	4.1	109	79	115	64	108	40	Failed																												
<u>Interior, Nominal 3-bag-per-cu-yd Cement Factor</u>																																					
Con-8-3A	0.59	4.6	92	81	91	70	88	52	83	63	83	49	79	48	80	90	78	81	73	70																	
Con-9-3B(1)	0.59	4.7	NR	--	Failed																																
Con-11-7	0.61	4.3	71	NR	72	--	72	--	Failed																												
Con-12-8(2)	0.59	3.3	90	82	87	68	87	27	Failed																												
Con-14-9B(2)	0.59	3.3	105	58	NR	51	NR	25	Failed																												

-- Dashed lines in "V<sup>2</sup>" column indicate that end of specimen was too rough to obtain satisfactory reading.  
 NR denotes that a satisfactory reading was not obtained although an attempt was made to obtain a satisfactory reading.

Air-entraining Admixture Study\*

The purpose of this study is to determine the relative effect of several commercial admixtures on the durability of concrete. In November 1944, ninety (6- by 6- by 30-in.) concrete specimens containing eight admixtures were installed on the Treat Island exposure rack. The aggregates used in these specimens were natural siliceous sand and crushed traprock of 1-1/2-in. maximum size. One cement (type II) was used, and the concrete mixtures had nominal cement factors of 4.5, 5.25, and 6.0 bags per cu yd with a nominal slump of 3 in. The water-cement and sand-aggregate ratios were permitted to fluctuate as affected by the admixture. The test specimens were of one size, but of two types: columns and beams.

Table 1-CRA lists these specimens and gives their exposure record along with other pertinent information.

In November 1957, the following seven concrete beam specimens were returned to the laboratory for detailed studies.

<u>Specimen No.</u>	<u>Admixture Used</u>
AB5A	Admixture A
AB5B	Admixture A
AB4	Admixture A
PB5C	None
PB4	None
RB5A	Resin soap
RB4	Resin soap

The purpose of these studies was to determine why some specimens with no admixture and some specimens with admixture A survived 13 years exposure at Treat Island when similar concrete was found to be nonfrost-resistant by laboratory tests made in 1944. Similar tests conducted in 1958 gave the same results as the 1944 tests. The laboratory studies did not indicate conclusively the reason for the survival of these specimens, but they did indicate the following:

---

\* See Central Concrete Laboratory, Concrete Research, Second Interim Report, Part I, "Laboratory Studies of Concrete Containing Air-entraining Admixtures" (July 1945).

## Section 25

- a. Specimens with high relative moduli (%E) are not necessarily undamaged by exposure at Treat Island; microfractures were found in one specimen having a %E of 153.
- b. The reason for the survival of the specimens with no admixture and with admixture A was not the accidental inclusion of an air-entraining agent that produced an air-void system capable of imparting frost resistance, since no such void system is present.
- c. It is possible that the early termination of moist-curing of the specimens with admixture A increased their frost resistance by making them less readily saturable on exposure.

(Issued June 1959)

Table 1-CRA

Section 25

## Record of Testing of Concrete Columns and Beams, Air-entraining Admixture Study

1944- (Installed November 1944)

Center Bay, Rows 1 and 2

		Cement Factor (Nominal)		1944-1953 Readings										1005 Cycles, 1953	
Specimen No.	Type Specimen	bags/cu yd	Air %	0	110	215	333	464	569	730	819	920			
				Cycles 1944	Cycles 1945	Cycles 1946	Cycles 1947	Cycles 1948	Cycles 1949	Cycles 1950	Cycles 1951	Cycles 1952	Cycles 1953	Pulse Veloc fps	$\frac{V}{V^2}$
Admixture A															
AC5A	Column*	5.25	1.9	Broken at installation											
AB5A	Beam*			100	120	127	133	132	134	136	136	139	137	15,330	100
AC5B	Column			100	119	128	129	129	130	131	131	135	138	15,430	100
AB5B	Beam			100	120	131	135	135	135	136	136	140	143	15,150	100
AC5C	Column			100	119	127	130	130	132	131	131	133	138	15,725	100
AB5C	Beam			100	120	131	136	135	138	138	138	140	144	15,530	100
AC4	Beam	4.5	2.0	100	120	136	136	138	133	138	138	141	146	14,880	100
AB4	Beam			100	119	134	139	137	140	141	140	142	148	15,060	100
AC6	Column	6.0	1.8	100	118	127	129	104	88	Failed					
AB6	Beam			100	118	127	129	128	130	129	129	131	136	16,020	100
Paraffin Oil															
OC5A	Column	5.25	3.9	100	109	113	116	115	115	117	114	118	121	15,430	100
OB5A	Beam			100	110	117	118	118	117	119	118	121	123	15,625	100
OC5B	Column			100	106	115	116	115	114	115	113	115	119	15,150	100
OB5B	Beam			100	109	115	116	116	115	116	115	117	120	15,530	100
OC5C	Column			100	110	120	122	122	121	122	121	125	127	15,430	100
OB5C	Beam			100	108	114	115	115	115	116	115	117	120	15,245	100
OC4	Column	4.5	7.5	100	110	115	116	117	116	117	115	118	121	14,795	100
OB4	Beam			100	107	111	112	111	108	110	109	110	112	14,370	100
OC6	Column	6.0	5.6	100	111	114	115	116	113	115	113	116	119	15,430	100
OB6	Beam			100	111	116	118	118	119	119	120	120	124	15,150	100
Admixture B															
ZC5A	Column	5.25	4.9	100	108	115	115	114	116	116	115	117	120	15,825	100
ZB5A	Beam			100	106	112	114	112	114	114	114	114	120	15,725	100
ZC5B	Column			100	106	115	117	115	113	112	111	113	120	14,705	100
ZB5B	Beam			100	101	109	112	110	110	110	110	112	115	15,530	100
ZC5C	Column			100	106	115	117	115	116	117	117	120	123	15,530	100
ZB5C	Beam			100	105	112	113	112	112	112	112	114	117	14,970	100
ZC4	Column	4.5	4.7	100	104	112	112	112	112	111	110	112	116	15,725	100
ZB4	Beam			100	102	110	112	110	109	111	110	111	113	15,430	100
ZC6	Column	6.0	6.0	100	105	111	112	111	111	112	111	114	117	15,625	100
ZB6	Beam			100	106	117	119	115	117	119	117	121	123	15,150	100
Resin Soap + CaCl <sub>2</sub>															
CC5A	Column	5.25	7.8	100	106	112	115	112	111	111	114	113	99	14,970	100
CB5A	Beam			100	104	111	112	111	108	111	108	112	115	14,705	100
CC5B	Column			100	109	118	121	119	120	121	119	123	125	15,245	100
CB5B	Beam			100	107	116	116	114	116	116	113	117	119	14,880	100
CC4	Column	4.5	5.2	100	107	114	115	114	113	113	112	114	116	15,335	100
CB4	Beam			100	107	112	113	110	110	110	109	113	114	15,060	100
CC6	Column	6.0	6.4	100	107	113	114	113	113	113	112	114	117	15,335	100
CB6	Beam			100	108	113	115	113	113	113	113	115	118	15,060	100
Without Admixture															
PC5A	Column	5.25	1.6	100	109	113	Failed								
PB5A	Beam			100	102	Failed									
PC5B	Column			100	109	113	114	Failed							
PB5B	Beam			100	110	115	115	115	115	117	117	Failed			
PC5C	Column			100	111	118	116	111	116	118	118	Failed			
PB5C	Beam			100	110	115	115	113	112	113	111	113	116	15,335	100
PC4	Column	4.5	3.3	100	109	117	118	118	129	118	117	119	122	15,060	100
PB4	Beam			100	109	111	115	113	113	113	111	112	113	14,970	100
PC6	Column	6.0	1.7	100	106	111	112	Failed							
PB6	Beam			100	110	115	117	115	115	118	118	118	119	14,705	100

(Continued)

\* A column is cast with its long axis vertical; a beam is cast with its long axis horizontal.

(1 of 4 sheets)

(Revised Aug 1963)  
Table 1-CRA (Continued)

Section 25

Specimen No.	Type Specimen	Cement Factor (Nominal) bags/cu yd	Air %	1944-1953 Readings										1005 Cycles, 1953	
				0	110	215	333	464	569	730	819	920	Pulse Veloc fps	psi <sup>2</sup>	
				Cycles 1944	Cycles 1945	Cycles 1946	Cycles 1947	Cycles 1948	Cycles 1949	Cycles 1950	Cycles 1951	Cycles 1952			
Resin Soap															
RC5A	Column	5.25	6.5	100	112	118	120	118	118	121	118	120	123	15,150	100
RB5A	Beam			100	108	113	115	115	116	117	115	119	122	14,880	100
RC5A1	Column			100	111	115	116	115	117	118	116	118	121	15,150	100
RB5A1	Beam			100	109	113	115	115	116	117	116	118	121	15,060	100
RC5B	Column			100	111	119	120	121	121	122	118	121	126	14,970	100
RB5B	Beam			100	110	115	117	117	117	118	116	118	120	15,060	100
RC5C	Column			100	110	114	117	115	116	116	114	118	120	15,060	100
RB5C	Beam			100	108	113	115	114	114	114	114	114	117	14,880	100
RC4	Column	4.5	7.8	100	112	119	120	117	116	116	114	116	119	14,535	100
RB4	Beam			100	110	114	114	114	111	111	110	111	111	14,450	100
RC6	Column	6.0	6.5	100	110	113	114	114	113	113	111	113	116	15,335	100
RB6	Beam			100	109	120	119	122	118	119	118	119	116	15,060	100
Tallow (Beef)															
TC5A	Column	5.25	4.0	100	111	118	119	118	115	112	100	Failed	Failed		
TB5A	Beam			100	108	110	113	113	113	113	92	Failed			
TC5B	Column			100	109	121	125	123	124	121	114	93			
TB5B	Beam			100	104	111	114	113	111	112	107	Failed			
TC5C	Column			100	109	96	Failed						Failed	14,970	100
TB5C	Beam			100	108	113	115	113	114	115	113	113			
TC4	Column	4.5	3.4	100	109	117	119	115	126	112	107	96	Failed	14,880	100
TB4	Beam			100	104	108	109	106	111	110	109	109	110		
TC6	Column	6.0	3.6	100	109	114	116	115	109	97	92	90	Failed	15,530	100
TB6	Beam			100	111	120	123	122	121	122	121	123	124		
Admixture C															
DC5A	Column	5.25	6.5	100	109	114	116	115	117	117	114	117	118	15,060	100
DB5A	Beam			100	108	115	117	116	116	116	115	116	117	15,150	100
DC5B	Column			100	106	111	113	111	111	112	115	110	116	14,880	100
DB5B	Beam			100	111	115	116	115	116	117	113	116	120	14,705	100
DC5C	Column			100	111	118	120	118	118	118	117	120	118	14,795	100
DB5C	Beam			100	109	113	116	116	114	114	111	114	116	14,535	100
DC4	Column	4.5	8.1	100	109	114	116	114	111	111	107	109	108	14,450	100
DB4	Beam			100	109	114	112	109	107	107	105	106	108	14,045	100
DC6	Column	6.0	6.1	100	109	116	116	116	113	114	111	115	117	14,970	100
DB6	Beam			100	111	119	122	119	120	120	118	120	120	14,970	100
Admixture D															
HC5A	Column	5.25	8.0	100	111	116	118	117	116	117	115	118	121	15,335	100
HB5A	Beam			100	110	118	118	117	117	118	117	119	123	15,245	100
HC5B	Column			100	109	113	116	116	117	117	114	118	118	14,880	100
HB5B	Beam			100	109	116	119	118	118	120	119	121	123	14,620	100
HC5C	Column			100	113	120	117	115	117	119	117	119	122	15,245	100
HB5C	Beam			100	110	115	116	116	115	115	114	117	120	14,795	100
HC4	Column	4.5	9.4	100	113	118	120	118	118	118	121	118	120	14,970	100
HB4	Beam			100	112	115	115	114	112	112	111	112	Failed	15,625	100
HC6	Column	6.0	6.0	100	112	117	120	118	120	120	120	122	124		
HB6	Beam			100	111	116	118	117	119	117	116	119	122		

Exposure Rack, Row 2 (W to E)

1954-1962 Readings									
1116	1261	1428	1572	1643	1793	1864	2005	2094	
Cycles 1954	Cycles 1955	Cycles 1956	Cycles 1957	Cycles 1958	Cycles 1959	Cycles 1960	Cycles 1961	Cycles 1962	
$\psi^2$	$\psi^2$	$\psi^2$	$\psi^2$	$\psi^2$	$\psi^2$	$\psi^2$	$\psi^2$	$\psi^2$	

Admixture A

AB5A	Beam	5.25	1.9	145	101	147	105	150	99	153	Returned to laboratory November 1957											
AC5B	Column			141	104	142	105	149	98	148	93	151	97	155	90	142	92	148	99	144	113	
AB5B	Beam			148	106	148	109	153	106	153	Returned to laboratory November 1957											
AC5C	Column			140	101	142	104	150	95	138	97	150	103	154	97	151	99	148	95	141	107	
AB5C	Beam			147	105	147	105	150	91	144	97	151	103	155	98	149	101	149	99	142	105	

(Continued)

(Sheet 2)

(Revised Sept 1968)  
Table 1-CRA (Continued)

Section 25

Exposure Rack, Row 2 (W to E)

		Cement Factor (Nominal) bags/ cu yd	Air %	1954-1962 Readings																	
Specimen No.	Type Specimen			1116 Cycles 1954		1261 Cycles 1955		1428 Cycles 1956		1572 Cycles 1957		1643 Cycles 1958		1793 Cycles 1959		1864 Cycles 1960		2005 Cycles 1961		2094 Cycles 1962	
				AE	AV <sup>2</sup>	AE	AV <sup>2</sup>	AE	AV <sup>2</sup>	AE	AV <sup>2</sup>	AE	AV <sup>2</sup>	AE	AV <sup>2</sup>	AE	AV <sup>2</sup>	AE	AV <sup>2</sup>	AE	AV <sup>2</sup>
				Exposure rack, Row 2 (W to E)																	
Admixture A (Continued)																					
AC4 AB4	Column Beam	4.5	2.0	147 149	104 106	147 150	108 108	146 158	100 101	152 153	98 Returned to laboratory November 1957	157 Returned to laboratory November 1957	105 Returned to laboratory November 1957	160 Returned to laboratory November 1957	99 Returned to laboratory November 1957	152 Returned to laboratory November 1957	101 Returned to laboratory November 1957	152 Returned to laboratory November 1957	102 Returned to laboratory November 1957	147 Returned to laboratory November 1957	108 Returned to laboratory November 1957
AB6	Beam	6.0	1.8	137	100	133	98	145	**	137	90	146	91	149	87	144	88	141	95	133	99
Paraffin Oil																					
OC5A OB5A OC5B OB5B OC5C OB5C	Column Beam Column Beam Column Beam	5.25	3.9	122 124 121 122 129 122	104 104 108 106 104 104	122 124 121 123 129 122	101 105 106 105 103 105	129 132 128 130 135 127	** 96 99 104 -- 98	126 130 125 128 132 126	114 100 104 104 -- 102	127 135 129 133 136 128	102 102 108 104 -- 102	132 139 132 135 147 131	94 98 102 100 -- 97	127 133 129 130 155 125	96 101 103 101 -- 99	127 133 130 129 171 124	98 100 99 101 -- 96	119 131 127 118 154 114	94 104 85 103 -- 102
OC4 OB4	Column Beam	4.5	7.5	122 111	104 102	122 110	104 102	127 116	93 96	123 110	101 98	126 114	102 97	123 112	93 86	103 113	80 102	98 102	79 91	82 86	71 90
OC6 OB6	Column Beam	6.0	5.6	126 127	103 105	121 126	103 108	127 132	87 93	126 131	100 103	134 131	103 104	130 138	98 98	125 131	98 100	126 131	98 101	124 123	101 110
Admixture B																					
ZC5A ZB5A ZC5B ZB5B ZC5C ZB5C	Column Beam Column Beam Column Beam	5.25	4.9	122 121 119 117 126 116	104 104 -- 106 101 104	122 122 Failed 118 126 116	104 105 Failed 108 99 105	130 129 124 124 129 123	101 96 122 95 122 101	128 121 104 122 133 115	100 121 104 104 97 105	130 125 104 124 105 120	105 104 132 108 105 104	135 132 99 128 96 122	97 128 99 99 138 117	130 128 100 122 95 102	97 100 127 99 138 102	129 127 100 122 95 117	101 99 127 103 88 100	120 122 109 117 138 112	108 109 -- 116 -- 100
ZC4 ZB4	Column Beam	4.5	4.7	116 114	104 104	116 112	100 105	117 108	100 95	117 104	81 92	118 106	84 93	126 91	-- 76	161 74	-- 76	153 128	-- --	125 128	-- --
ZC6 ZB6	Column Beam	6.0	6.0	117 125	105 109	118 126	105 110	124 133	99 99	124 125	103 107	120 133	106 110	127 137	100 93	122 132	100 93	121 131	99 105	117 125	105 105
Resin Soap + CaCl <sub>2</sub>																					
CC5A CB5A CC5B CB5B	Column Beam Column Beam	5.25	7.8	99 115 127 120	105 104 126 101	99 116 126 121	106 107 104 100	102 121 126 123	95 121 92 95	101 120 131 124	97 100 96 96	102 121 135 128	101 102 101 102	102 123 136 128	99 97 95 94	100 118 127 123	99 98 97 94	98 117 130 122	100 99 98 95	94 114 122 118	108 98 102 102
CC4 CB4	Column Beam	4.5	5.2	115 116	100 104	117 116	101 105	119 120	-- 93	119 119	-- 96	123 119	-- 106	124 124	-- 98	115 118	-- 97	117 117	-- 94	107 110	-- 105
CC6 CB6	Column Beam	6.0	6.4	118 121	103 104	119 122	103 105	118 125	94 97	123 121	95 96	126 126	99 103	130 130	95 98	122 121	96 100	123 124	92 100	116 119	95 105
Without Admixture																					
PB5C	Beam	5.25	1.6	117	104	117	105	122	94	120	Returned to laboratory November 1957										
PC4 PB4	Column Beam	4.5	3.3	121 111	104 102	119 106	105 102	120 96	89 91	111 78	89 Returned to laboratory November 1957	109 Returned to laboratory November 1957	92 Returned to laboratory November 1957	Returned to laboratory October 1958							
PB6	Beam	6.0	1.7	122	91	125	92	143	---	151	---	157	---	Returned to laboratory October 1958							
Resin Soap																					
RC5A RB5A RC5A1 RB5A1 RC5B RB5B RC5C RB5C	Column Beam Column Beam Column Beam Column Beam	5.25	6.5	126 123 123 126 123 122 118	104 105 104 106 106 106 104	126 123 124 124 126 122 118	102 106 106 102 105 106 108	132 128 127 129 132 125 124	98 99 98 99 102 101 99	129 126 127 127 129 124 121	99 Returned to laboratory November 1957 100 103 103 103 100 99	132 Returned to laboratory November 1957 130 128 104 129 125 129	101 102 102 103 104 102 105	135 Returned to laboratory November 1957 131 133 133 129 126 99	97 Returned to laboratory November 1957 95 128 104 104 104 121	128 Returned to laboratory November 1957 126 97 128 Lost overboard in storm, Feb 1959 Lost overboard in storm, Feb 1959 Lost overboard in storm, Feb 1959	106 Returned to laboratory November 1957 102 128 98 128 128 101	128 Returned to laboratory November 1957 126 128 98 128 128 119	101 Returned to laboratory November 1957 100 98 98 101 101 101	122 Returned to laboratory November 1957 120 122 122 116 112 116	105 Returned to laboratory November 1957 101 100 100 98 100 106
RC4 RB4	Column Beam	4.5	7.8	119 114	101 101	119 113	106 104	118 114	101 93	119 115	99 Returned to laboratory November 1957	122 Returned to laboratory November 1957	104 Returned to laboratory November 1957	125 Returned to laboratory November 1957	97 Returned to laboratory November 1957	121 Returned to laboratory November 1957	98 Returned to laboratory November 1957	121 Returned to laboratory November 1957	96 Returned to laboratory November 1957	111 Returned to laboratory November 1957	90 Returned to laboratory November 1957
RC6 RB6	Column Beam	6.0	6.5	117 125	99 100	117 126	104 105	121 131	94 93	120 128	96 99	124 132	100 104	125 135	90 99	119 130	91 98	117 127	93 99	112 112	91 97

(Continued)

-- Dashed lines in " $\%V^2$ " column indicate that end of specimen was too rough to obtain satisfactory reading.  
\*\* These readings were inadvertently omitted in 1956.

(Sheet 3)

(Revised Jan 1972)  
Table 1-CRA (Continued)

Section 25  
Exposure Rack, Row 2 (W to E)

										1954-1962 Readings																Exposure Rack, Row 2 (W to E)			
Specimen No.	Type Specimen	Cement Factor (Nominal) bags/cu yd	Air %	1116 Cycles 1954		1261 Cycles 1955		1428 Cycles 1956		1572 Cycles 1957		1643 Cycles 1958		1793 Cycles 1959		1864 Cycles 1960		2005 Cycles 1961		2094 Cycles 1962									
				AE	AV <sup>2</sup>	AE	AV <sup>2</sup>	AE	AV <sup>2</sup>	AE	AV <sup>2</sup>	AE	AV <sup>2</sup>	AE	AV <sup>2</sup>	AE	AV <sup>2</sup>	AE	AV <sup>2</sup>	AE	AV <sup>2</sup>	AE	AV <sup>2</sup>						
				Tallow (Beef)																									
TB5C	Beam	5.25	4.0	119	106	118	108	123	90	118	102	123	105	127	100	122	102	121	101	109	101								
TB4	Beam	4.5	3.4	112	105	112	106	112	95	106	100	111	101	110	92	101	89	94	82	84	82								
TB6	Beam	6.0	3.6	127	103	121	103	128	95	124	100	133	104	140	97	135	101	131	99	126	106								
Admixture C																													
DC5A	Column	5.25	6.5	121	102	121	104	127	99	122	100	127	108	130	91	122	94	122	100	115	99								
DB5A	Beam			120	102	120	104	126	95	124	101	134	105	129	94	123	99	122	100	115	104								
DC5B	Column			116	101	115	102	121	97	118	98	121	102	124	94	118	97	118	99	113	102								
DB5B	Beam			119	105	120	106	124	96	121	102	124	106	125	97	120	100	118	100	113	105								
DC5C	Column			122	101	122	101	123	98	119	101	127	103	131	96	122	98	122	99	117	105								
DB5C	Beam			116	104	117	105	122	97	118	100	121	101	124	95	118	96	117	97	112	105								
DC4	Column	4.5	8.1	112	101	113	104	119	97	118	103	122	102	122	99	109	100	99	97	84	--								
DB4	Beam			109	101	108	105	111	93	108	103	110	103	115	95	109	97	103	95	86	100								
DC6	Column	6.0	6.1	119	105	120	106	125	95	124	101	125	102	128	100	123	101	123	102	118	105								
DB6	Beam			121	104	126	104	130	98	129	98	132	103	136	99	129	105	128	98	124	105								
Admixture D																													
HC5A	Column	5.25	8.0	123	100	117	100	122	98	120	104	129	104	132	98	126	100	126	100	120	106								
HB5A	Beam			126	102	126	106	133	96	128	103	133	103	137	98	131	103	131	102	128	109								
HC5B	Column			122	102	122	105	128	98	120	100	123	105	131	98	126	102	126	101	121	110								
HB5B	Beam			128	106	127	107	134	104	130	104	134	104	139	99	128	103	125	101	125	109								
HC5C	Column			125	106	126	108	132	101	126	102	132	106	136	100	128	102	131	99	126	106								
HB5C	Beam			122	105	119	106	126	104	122	105	126	106	130	100	122	105	121	104	116	113								
HC4	Column	4.5	9.4	120	106	112	106	126	86	122	98	125	103	124	95	116	97	113	98	108	108								
HC6	Column	6.0	6.0	128	105	122	107	136	95	133	101	136	105	140	99	108	102	131	101	128	112								
HB6	Beam			124	109	124	106	129	91	126	103	129	107	133	99	127	101	123	101	121	109								
1963-1971 Readings																						Exposure Rack, Row 2 (W to E)							
				2200 Cycles 1963		2335 Cycles 1964		2498 Cycles 1965		2628 Cycles 1966		2784 Cycles 1967		2969 Cycles 1968		3123 Cycles 1969		3276 Cycles 1970		3445 Cycles 1971									
				AE	AV <sup>2</sup>	AE	AV <sup>2</sup>	AE	AV <sup>2</sup>	AE	AV <sup>2</sup>	AE	AV <sup>2</sup>	AE	AV <sup>2</sup>	AE	AV <sup>2</sup>	AE	AV <sup>2</sup>	AE	AV <sup>2</sup>								
Admixture A																													
AC5B	Column	5.25	1.9	146	107	142	60	143	107	166	100	169	102	162	96	175	91	165	87	165	--								
AC5C	Column			138	104	133	87	136	100	136	--	NR††	--	F	--	--	--	--	--	--	--								
AB5C	Beam			143	108	140	100	140	103	140	96	135	103	135	93	140	92	127	87	109	--								
AC4	Column	4.5	2.0	148	102	147	--	141	--	144	--	147	--	156	--	138	--	175	--	172	--								
AB6	Beam	6.0	1.8	125	84	114	91	109	98	121	66	121	61	F	--	--	--	--	--	--	--								
Paraffin Oil																													
OC5A	Column	5.25	3.9	117	39	115	95	113	105	115	--	113	--	113	--	113	--	111	--	108	--								
OB5A	Beam			125	89	129	101	126	104	124	--	124	--	126	--	128	--	130	--	124	--								
OC5B	Column			124	90	132	--	143	--	199	--	NR	--	209	--	NR	--	74	--	F	--								
OB5B	Beam			123	106	121	105	123	108	125	93	123	100	123	99	125	--	128	--	125	--								
OC5C	Column			187	--	193	--	199	--	199	--	NR	--	254	--	NR	--	71	--	73	--								
OB5C	Beam			91	108	89	--	87	--	85	--	81	--	79	--	77	--	74	--	69	--								
OC4	Column	4.5	7.5	80	--	65	--	60	--	F	--	--	--	--	--	--	--	--	--	--	--								
OB4	Beam			76	--	119	--	F†	--	--	--	--	--	--	--	--	--	--	--	--	--								
OC6	Column	6.0	5.6	121	108	119	--	114	--	116	--	116	--	118	--	118	--	131	--	170	--								
OB6	Beam			122	112	118	94	114	121	116	89	114	101	109	100	111	--	116	--	111	--								
Admixture B																													
ZC5A	Column	5.25	4.9	124	107	122	97	118	112	116	98	116	105	118	--	123	--	123	--	123	--								
ZB5A	Beam			123	105	118	100	116	117	118	91	118	99	118	94	118	--	113	--	88	--								
ZB5B	Beam			115	80	113	101	118	115	118	95	118	104	118	100	120	88	115	80	95	--								
ZC5C	Column			143	--	157	--	154	--	160	--	NR	--	160	--	166	--	166	--	105	--								
ZB5C	Beam			112	--	112	--	110	--	110	--	106	--	108	--	108	--	106	--	NR	--								

(Continued)

-- Dashed lines in " $\%V^2$ " column indicate that end of specimen was too rough to obtain satisfactory reading.

† F denotes specimen has failed.

†† NR denotes that a satisfactory reading was not obtained as specimen would not respond to flexural vibration. (Sheet 4)

(Revised Jan 1973)  
Table 1-CRA (Continued)

Section 25

Exposure Rack, Row 2 (W to E)

		1963-1971 Readings																			
Specimen No.	Type Specimen	Cement Factor (Nominal) bags/cu yd	Air %	2200 Cycles 1963		2335 Cycles 1964		2498 Cycles 1965		2628 Cycles 1966		2784 Cycles 1967		2969 Cycles 1968		3123 Cycles 1969		3276 Cycles 1970		3445 Cycles 1971	
				$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$
				Admixture B (Continued)																	
ZC4	Column	4.5	4.7	143	--	173	--	F													
ZB4	Beam			F†																	
ZC6	Column	6.0	6.0	115	104	110	103	112	107	114	92	NR††	98	112	--	117	--	112	--	108	--
ZB6	Beam			125	113	122	96	122	112	153	--	150	--	112	--	112	--	112	--	110	--
Resin Soap + CaCl <sub>2</sub>																					
CC5A	Column	5.25	7.8	94	104	88	99	84	102	84	--	78	--	74	--	78	--	60	--	62	--
CB5A	Beam			114	101	109	97	107	107	117	--	112	--	110	--	110	--	110	--	108	--
CC5B	Column			125	99	120	--	120	--	120	--	120	--	117	--	120	--	120	--	NR	--
CB5B	Beam			121	104	121	--	116	--	119	--	116	--	106	--	108	--	99	--	75	--
CC4	Column	4.5	5.2	101	--	91	--	116	--	200	--	NR	--	F							
CB4	Beam			110	108	104	97	101	95	140	--	NR	--	F							
CC6	Column	6.0	6.4	115	92	106	--	101	--	159	--	F									
CB6	Beam			119	95	114	98	110	108	110	--	110	--	100	--	102	--	Failed			
Resin Soap																					
RC5A	Column	5.25	6.5	122	98	119	96	119	90	122	86	119	90	114	95	119	84	114	80	114	--
RC5A1	Column			119	106	118	100	115	108	116	--	116	--	116	--	118	--	116	--	116	--
RB5A1	Beam			119	93	119	98	125	102	125	93	125	--	125	--	135	--	127	--	127	--
RB5C	Beam			112	78	108	98	108	106	108	83	108	--	108	--	113	--	108	--	104	--
RC4	Column	4.5	7.8	112	98	108	--	108	--	103	--	NR	--	111	--	127	--	127	--	F	--
RC6	Column	6.0	6.5	110	92	103	--	105	--	122	--	NR	--	143	--	149	--	149	--	F	--
RB6	Beam			114	99	112	100	110	108	108	81	101	--	86	--	86	--	74	--	F	--
Tallow (Beef)																					
TB5C	Beam	5.25	4.0	114	86	112	--	110	--	108	--	106	--	101	--	103	--	103	--	99	--
TB4	Beam	4.5	3.4	72	82	F															
TB6	Beam	6.0	3.6	129	93	124	86	121	101	124	86	119	--	109	--	111	--	106	--	95	--
Admixture C																					
DC5A	Column	5.25	6.5	116	108	112	103	114	108	124	83	117	--	110	--	110	--	108	--	110	--
DB5A	Beam			116	102	112	104	107	105	112	98	112	106	107	102	107	94	109	90	109	--
DC5B	Column			114	101	112	--	110	--	125	--	117	--	105	--	110	--	110	--	108	--
DB5B	Beam			113	106	111	104	111	112	109	98	107	98	107	94	109	--	107	--	105	--
DC5C	Column			117	104	115	97	115	105	115	--	115	--	108	--	103	--	94	--	83	--
DB5C	Beam			110	82	108	93	101	110	107	92	105	93	103	90	101	--	96	--	122	--
DC4	Column	4.5	8.1	84	--	68	--	74	--	F											
DB4	Beam			81	93	66	70	67	--	F											
DC6	Column	6.0	6.1	118	92	114	--	110	--	112	--	112	--	107	--	109	--	111	--	113	--
DB6	Beam			124	73	119	--	115	--	115	--	111	--	106	--	106	--	104	--	104	--
Admixture D																					
HC5A	Column	5.25	8.0	120	109	116	63	114	108	114	91	114	104	107	102	107	93	105	--	106	--
HB5A	Beam			124	110	120	95	118	105	120	92	115	105	120	101	120	95	120	--	118	--
HC5B	Column			121	105	121	100	118	103	121	94	121	101	117	90	118	--	123	--	123	--
HB5B	Beam			120	114	117	102	113	116	114	94	114	--	124	--	121	--	119	--	115	--
HC5C	Column			126	95	126	--	119	--	124	--	NR	--	134	--	131	--	131	--	NR	--
HB5C	Beam			116	105	109	104	109	117	109	97	109	102	104	93	109	--	109	--	83	--
HC4	Column	4.5	9.4	101	96	91	--	87	--	89	--	NR	--	F	--						
HC6	Column	6.0	6.0	128	103	190	104	98	107	100	89	100	98	98	101	100	87	98	84	98	--
HB6	Beam			121	108	119	96	117	111	117	83	117	99	110	98	110	--	105	--	102	--

-- Dashed lines in " $\frac{1}{2}V^2$ " column indicate that end of specimen was too rough to obtain satisfactory reading.

† F denotes specimen has failed.

†† NR denotes a satisfactory reading was not obtained as specimen would not respond to flexural vibration.

(Sheet 5)

(Revised August 1977)  
Table 1-CRA (Continued)

Section 25  
Exposure Rack, Row 2 (W to E)

										1972-		Readings			
Specimen No.	Type Specimen	Cement Factor (Nominal) bags/cu yd	Air %	3602		3742		3878		3990		4136		4213	
				Cycles	Cycles	Cycles	Cycles	Cycles	Cycles	Cycles	Cycles				
				1972	1973	1974	1975	1976	1977						
				$\%E$	$\%V^2$	$\%E$	$\%V^2$	$\%E$	$\%V^2$	$\%E$	$\%V^2$	$\%E$	$\%V^2$	$\%E$	$\%V^2$
Admixture A															
AC5B	Column	5.25	1.9	159	--	244	--	172	--	179	--	163	--	166	--
AB5C	Beam			93	--	143	--	128	--	Gone					
AC4	Column	4.5	2.0	165	--	171	--	272	--	Failed					
Paraffin Oil															
OC5A	Column	5.25	3.9	101	--	94	--	96	--	96	--	Gone			
OB5A	Beam			120	--	119	--	117	--	112	--	119	--	101	--
OC5B	Column			F†	--										
OB5B	Beam			120	--	147	--	186	--	Failed					
OC5C	Column			79	--	72	--	NR	--	Gone					
OB5C	Beam			62	--	58	--	52	--	51	--	Gone			
OC6	Column	6.0	5.6	164	--	155	--	NR	--	Gone					
OB6	Beam			111	--	102	--	100	--	Failed					
Admixture B															
ZC5A	Column	5.25	4.9	121	--	121	--	119	--	114	--	Failed			
ZB5A	Beam			104	--	176	--	NR	--	Gone					
ZB5B	Beam			85	--	91	--	172	--	Failed					
ZC5C	Column			100	--	215	--	215	--	Failed					
ZB5C	Beam			184	--	102	--	209	--	Failed					
ZC6	Column	6.0	6.0	91	--	126	--	95	--	75	--	Gone			
ZB6	Beam			112	--	112	--	78	--	114	--	82	--	Failed	
Resin Soap + CaCl <sub>2</sub>															
CC5A	Column	5.25	7.8	F	--					Gone					
CB5A	Beam			85	--	62	--	NR	--	Gone					
CC5B	Column			F	--										
CB5B	Beam			F	--										
Resin Soap															
RC5A	Column	5.25	6.5	116	--	116	--	111	--	113	--	Gone			
RC5A1	Column			114	--	119	--	NR	--	Gone					
RB5A1	Beam			122	--	120	--	120	--	122	--	Gone			
RB5C	Beam			97	--	88	--	119	--	119	--	117	--	108	--
Tallow (Beef)															
TB5C	Beam	5.25	4.0	F	--										
TB6	Beam	6.0	3.6	83	--	NR	--	F	--						
Admixture C															
DC5A	Column	5.25	6.5	105	--	105	--	96	--	87	--	118	--	135	--
DB5A	Beam			107	--	112	--	105	--	105	--	78	--	98	--
DC5B	Column			106	--	92	--	182	--	182	--	Gone			
DB5B	Beam			96	--	92	--	132	--	Failed					
DC5C	Column			F	--										
DB5C	Beam			72	--	F									
DC6	Column	6.0	6.1	88	--	122	--	153	--	Failed					
DB6	Beam			95	--	80	--	157	--	Gone					
Admixture D															
HC5A	Column	5.25	8.0	105	--	94	--	103	--	99	--	95	--	130	--
HB5A	Beam			116	--	114	--	114	--	112	--	79	--	79	--
HC5B	Column			120	--	128	--	123	--	118	--	133	--	78	--
HB5B	Beam			117	--	124	--	114	--	116	--	114	--	126	--
HC5C	Column			252	--	252	--	234	--	Failed					
HB5C	Beam			79	--	68	--	NR	--	Gone					
HC6	Column	6.0	6.0	95	--	98	--	96	--	90	--	116	--	116	--
HB6	Beam			96	--	138	--	90	--	90	--	67	--	Failed	

-- Dashed lines in "%V<sup>2</sup>" column indicate that end of specimen was too rough to obtain satisfactory reading.

† F denotes specimen has failed.

NR Denotes no reading obtained.

(Sheet 6)

Omaha District Aggregate Program1956 installation

In December 1956, six concrete beams (6 by 6 by 30 in.) were installed on the Treat Island exposure rack to provide field durability data on concrete specimens fabricated as a part of the Omaha District, CE, Aggregate Program. This installation was made up of two series of beams, one containing the aggregate and cement combinations being used for concrete for the Oahe Dam, and the other containing a sand-gravel with a limestone addition, typical of limestone-sweetened concrete in the Lincoln-Omaha area.

Table 1-OD lists these specimens and gives their exposure record along with pertinent mixture data.

Companion specimens (3-1/2 by 4-1/2 by 16 in.) to these Treat Island exposure specimens were subjected to laboratory freezing-and-thawing tests in the Missouri River Division Laboratory, Omaha, Nebr. The results of these laboratory tests are given below:

<u>Mixture</u>	<u>No. of Specimens Tested</u>	<u>Average %E at 300 Cycles of Freezing-and-Thawing</u>
Oahe	9 beams	86
Sand-gravel	9 beams	53

1964 installation

In November 1964, three concrete beams (6 by 6 by 30 in.) were installed on the Treat Island exposure rack as a part of the Omaha District, CE, Aggregate Program. These beams were representative of concrete and materials used in Big Bend Dam.

Table 2-OD lists these specimens and gives their exposure record along with pertinent mixture data.

(Revised August 1977)

Table 1-OD

Section 26

## Record of Testing of Concrete Beams, Omaha District Aggregate Program

1956- (Installed December 1956)

Beam No.	Fine Aggregate	Coarse Aggregate	Type Cement	Air %	Cement Factor bags/cu yd	Exposure Rack, Row 2 (W to E)													
						1956-1962 Readings													
						0 Cycles 1956	124 Cycles, 1957		195 Cycles 1958		345 Cycles 1959		416 Cycles 1960		557 Cycles 1961		646 Cycles 1962		
						$\bar{E}$	$\bar{E}$	Pulse Veloc fps	$\bar{V}^2$	$\bar{E}$	$\bar{V}^2$	$\bar{E}$	$\bar{V}^2$	$\bar{E}$	$\bar{V}^2$	$\bar{E}$	$\bar{V}^2$	$\bar{E}$	$\bar{V}^2$
Oahe-1	Natural	Limestone	II,	6.1	5.32	100	116	15,245	100	117	108	123	98	121	100	121	102	115	105
Oahe-2	sand	A*	low-	6.7	5.29	100	110	14,880	100	116	109	122	101	120	105	119	108	113	112
Oahe-3			alk	6.6	5.30	100	111	15,245	100	116	106	123	98	119	102	118	108	113	113
S-G-1	Sand-	Limestone	I	7.1	5.81	100	106	15,430	100	108	107	113	103	110	103	106	105	90	104
S-G-2	gravel	B**		6.4	5.86	100	103	15,530	100	106	105	111	101	102	98	74	93	F†	--
S-G-3				6.3	5.86	100	104	15,625	100	108	105	114	101	111	102	103	101	79	--

1963-1969 Readings																			
752 Cycles 1963		887 Cycles 1964		1050 Cycles 1965		1180 Cycles 1966		1336 Cycles 1967		1521 Cycles 1968		1675 Cycles 1969							
$\bar{E}$	$\bar{V}^2$	$\bar{E}$	$\bar{V}^2$	$\bar{E}$	$\bar{V}^2$	$\bar{E}$	$\bar{V}^2$	$\bar{E}$	$\bar{V}^2$	$\bar{E}$	$\bar{V}^2$	$\bar{E}$	$\bar{V}^2$						
Oahe-1	Natural	Limestone	II,	6.1	5.32	116	100	114	105	109	111	111	103	109	105	107	98	107	92
Oahe-2	sand	A*	low-	6.7	5.29	114	118	112	110	107	112	109	102	104	109	106	100	108	95
Oahe-3			alk	6.6	5.30	113	108	108	100	105	94	106	101	104	104	102	101	104	95
S-G-1	Sand-	Limestone	I	7.1	5.81	41F	61												
S-G-3	gravel	B**		6.3	5.86	F													

1970-1976 Readings																			
1828 Cycles 1970		1997 Cycles 1971		2154 Cycles 1972		2294 Cycles 1973		2430 Cycles 1974		2542 Cycles 1975		2688 Cycles 1976							
$\bar{E}$	$\bar{V}^2$	$\bar{E}$	$\bar{V}^2$	$\bar{E}$	$\bar{V}^2$	$\bar{E}$	$\bar{V}^2$	$\bar{E}$	$\bar{V}^2$	$\bar{E}$	$\bar{V}^2$	$\bar{E}$	$\bar{V}^2$						
Oahe-1	Natural	Limestone	II,	6.1	5.32	105	90	103	74	101	82	95	94	85	94	83	113	91	96
Oahe-2	sand	A*	low-	6.7	5.29	103	94	103	78	96	82	98	87	84	95	82	114	82	86
Oahe-3			alk	6.6	5.30	100	93	100	74	96	79	98	93	82	93	82	115	80	88

1977- Readings																			
2765 Cycles 1977																			
$\bar{E}$	$\bar{V}^2$																		
Oahe-1	Natural	Limestone	II,	6.1	5.32	95	92												
Oahe-2	sand	A*	low-	6.7	5.29	76	92												
Oahe-3			alk	6.6	5.30	90	78												

-- End of specimen too rough to obtain satisfactory reading.

\* Maximum size aggregate = 1-1/2 in.; slump for this mix = 2-3/4 to 3 in.

\*\* Maximum size aggregate = 1 in.; slump for this mix = 2 in.

† F denotes specimen has failed.

(Revised Jan 1972)

Table 2-0D

Section 26

Record of Testing of Concrete Beams, Omaha District Aggregate Program1964- (Installed November 1964)

Exposure Rack, Row 2 (W to E)											
Beam No.	Fine Aggregate	Coarse Aggregate	Type Cement	Air %	Cement Factor bags/cu yd	0 Cycles 1964			163 Cycles 1965		
						Pulse Vel <u>%E</u>	<u>fps</u>	<u>%V<sup>2</sup></u>	<u>%E</u>	<u>%V<sup>2</sup></u>	
Big Bend-1	Natural sand	Quartzite*	II, low alkali (C <sub>3</sub> A content less than 6%)	5.9	5.48	100	15,195	100	102	99	
Big Bend-2			5.8	5.48	100	15,195	100	103	101		
Big Bend-3			6.2	5.46	100	15,100	100	103	101		
						293 Cycles 1966		449 Cycles 1967		634 Cycles 1968	
						<u>%E</u>	<u>%V<sup>2</sup></u>	<u>%E</u>	<u>%V<sup>2</sup></u>	<u>%E</u>	<u>%V<sup>2</sup></u>
Big Bend-1	Natural sand	Quartzite*	II, low alkali (C <sub>3</sub> A content less than 6%)	5.9	5.48	106	104	102	110	53	66
Big Bend-2			5.8	5.48	106	103	104	107	63	58	
Big Bend-3			6.2	5.46	104	103	103	108	70	87	
						788 Cycles 1969		941 Cycles 1970		1110 Cycles 1971	
						<u>%E</u>	<u>%V<sup>2</sup></u>	<u>%E</u>	<u>%V<sup>2</sup></u>	<u>%E</u>	<u>%V<sup>2</sup></u>
Big Bend-1	Natural sand	Quartzite*	II, low alkali (C <sub>3</sub> A content less than 6%)	5.9	5.48	53	41	28F†	39	F	--
Big Bend-2			5.8	5.48	57	30	F†		--		
Big Bend-3			6.2	5.46	67	41	NR	38	F	--	

\* Maximum size aggregate, 1-1/2 in.; slump for this mix, 2-1/4 to 2-1/2 in.; water cement ratio, 4.93 gal/bag.

† F denotes specimen has failed.

NR A satisfactory reading was not obtained although an attempt was made to obtain one.

Kansas City District Aggregate Program1958 installation

In January 1958, eighteen concrete beams (6 by 6 by 30 in.) were installed on the Treat Island exposure rack to provide field durability data on concrete specimens containing certain aggregate materials commercially produced in the Kansas City District, CE. This installation is a part of an aggregate program being conducted by the Kansas City District. The concrete beams represented six different combinations of fine and coarse aggregate (3 beams per combination). All concrete mixtures contained type II low-alkali cement and an air-entraining admixture, and were designed to have a water-cement ratio of 5.0 gal per bag, a slump of 2 to 3 in., an air content of 4 to 7%, and a maximum aggregate size of 1-1/2 in.

Table 1-KCD lists these specimens and gives their exposure record along with other pertinent information.

Companion specimens (3-1/2 by 4-1/2 by 16 in.) to these Treat Island exposure specimens were subjected to laboratory freezing-and-thawing tests in the Missouri River Division Laboratory, Omaha, Nebr. The results of these laboratory tests are given below:

Mixture No.	No. of Beams Tested	Average %E at 300 Cycles of Freezing-and-thawing
1	9	29
2	9	31
3	9	9
4	9	25
5	9	59
6	9	73

1959 installation

In May 1959, eighteen concrete beams (6 by 6 by 30 in.) were installed on the Treat Island exposure rack; this installation is a part of the Kansas City District aggregate program. The concrete beams represented six different aggregate combinations of fine and coarse aggregate (3 beams per combination). All concrete mixtures contained type II cement and an air-entraining admixture, and were designed to have a water-cement ratio

of 5.0 gal per bag, a slump of 2 to 3 in., an air content of 4 to 7%, and a maximum aggregate size of 1-1/2 in.

Table 2-KCD lists these specimens and gives their exposure record along with other pertinent information.

Companion specimens (3-1/2 by 4-1/2 by 16 in.) to these Treat Island exposure specimens were subjected to laboratory freezing-and-thawing tests in the Missouri River Division Laboratory, Omaha, Nebr. The results of these laboratory tests are given below:

Mixture No.	No. of Beams Tested	Average %E at 300 Cycles of Freezing-and-Thawing
7	9	29
8	9	68
9	9	25
10	9	40
11	9	28
12	9	3

#### 1962 installation

In November 1962, nine concrete beams (6 by 6 by 30 in.) were installed on the Treat Island exposure rack; this installation is a part of the Kansas City District aggregate program. The concrete beams represented three different concrete mixtures (three beams per mixture). All concrete mixtures contained type II low-alkali cement and an air-entraining admixture, and were designed to have a water-cement ratio of 5.0 gal per bag, a slump of 2 to 3 in., an air content of 4 to 7%, and a maximum aggregate size of 1-1/2 in.

Table 3-KCD lists these specimens and gives their exposure record along with other pertinent information.

Companion specimens (3-1/2 by 4-1/2 by 16 in.) to these Treat Island exposure specimens were subjected to laboratory freezing-and-thawing tests in the Missouri River Division Laboratory, Omaha, Nebr. The results of these laboratory tests are given below:

Mixture No.	No. of Beams Tested	Average %E at 300 Cycles of Freezing-and-Thawing
13*	9	69
14**	9	56
15*	9	53

\* Specimens had 14 days of curing before start of test.

\*\* Specimens had 28 days of curing before start of test.

1963 installation

In December 1963, nine concrete beams (6 by 6 x 30 in.) were installed on the Treat Island exposure rack; this installation is a part of the Kansas City District aggregate program. The concrete beams represented three concrete mixtures (three beams per mixture). All concrete mixtures contained type II cement and an air-entraining admixture and were designed to have a cement factor of approximately 6 bags per cu yd, a slump of 2 to 3 in., and an air content of approximately 4-1/2 percent. The maximum aggregate size was 1-1/2 in. in two of the mixes and 3/4 in. in the other (mixture 17). One mixture (mixture 16) contained a cement-replacement material in addition to the type II cement.

Table 4-KCD lists these specimens and gives their exposure record along with other pertinent information.

Companion specimens (3-1/2 by 4-1/2 by 16 in.) to the Treat Island exposure specimens were subjected to laboratory freezing-and-thawing tests in the Missouri River Division Laboratory, Omaha, Nebr. The results of the laboratory tests are given below:

<u>Mixture No.</u>	<u>No. of Beams Tested</u>	<u>Avg %E at 300 Cycles of Freezing-and-Thawing</u>
16*	9	55
17**	9	3
18**	9	55

\* Specimens had 28 days curing in saturated lime-water before start of test.

\*\* Specimens had 14 days curing in saturated lime-water before start of test.

1969 installation

In May 1969, three concrete beams† (6 by 6 by 30 in.) were installed on the Treat Island exposure rack; this installation is a part of the

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† These beams had 28 days curing in saturated limewater before exposure.

Kansas City District aggregate program. The concrete beams represented three concrete batches (one beam per batch) of one concrete mixture. The concrete mixture was air-entrained and contained type II low-alkali portland cement and a cement-replacement material (20% by absolute volume). The mixture was designed to have a theoretical cement factor of 5.76 bags per cu yd, a slump of 2-1/2 in., and an air content of 4.7 to 5.0 percent. The maximum aggregate size (crushed limestone) was 1-1/2 in.

Table 5-KCD lists these specimens and gives their exposure record along with other pertinent information.

Companion specimens (3-1/2 by 4-1/2 by 16 in.) to the Treat Island exposure specimens were subjected to laboratory freezing-and-thawing tests in the Missouri River Division Laboratory, Omaha, Nebr. The results of the laboratory tests are given below:

Mixture No.	Batch No.	No. of Beams Tested	Avg %E After 300 Cycles of Freezing-and-Thawing
19	1	3*	61
19	2	2*	64
19	3	3*	65

\* These beams had 90 days of water curing prior to start of the laboratory freezing-and-thawing test.

#### 1974 installation

In July 1974, six concrete beams (6 by 6 by 30 in.) were installed on the Treat Island exposure rack; this installation is a part of the Kansas City District aggregate program. The concrete beams represented two concrete mixtures (three beams per mixture). The concrete mixtures (20 and 21) contained type II cement and an air-entraining admixture and were designed to have cement factors of approximately 5.3 and 5.7 bags per cu yd, slumps of 2-1/2 and 2 in., and air contents of 5 and 4.5 percent. Maximum aggregate sizes were 1-1/2 in. Mixture 20 contained a cement-replacement material.

Tables 6- and 7-KCD list these specimens and give their exposure record along with other pertinent data.

Companion specimens (3-1/2 by 4-1/2 by 16 in.) were subjected to laboratory freezing-and-thawing tests in the Missouri River Division Laboratory, Omaha, Nebr. The results of these tests are given below:

<u>Mixture No.</u>	<u>No. of Beams Tested</u>	<u>Avg %E at 300 Cycles of Freezing-and-Thawing</u>
20*	9	64
21**	9	35

\* Specimens were 90 days old when freezing-and-thawing cycles started.

\*\* Specimens were 14 days old when freezing-and-thawing cycles started.

(Revised Jan 1972)

Table 1-KCD

Section 27

## Mixture Data and Record of Testing of Concrete Beams, Kansas City District Aggregate Program

1957- (Installed January 1958)

Exposure Rack, Row 2 (W to E)

				1957-1963 Readings															
Beam No.	Mixture No.	Fine Aggregate	Coarse Aggregate	Cement Factor bags/cu yd	0 Cycles 1957	43 Cycles, 1958				193 Cycles 1959		264 Cycles 1960		405 Cycles 1961		494 Cycles 1962		600 Cycles 1963	
						FE	FE	fps	FV <sup>2</sup>	FE	FV <sup>2</sup>	FE	FV <sup>2</sup>	FE	FV <sup>2</sup>	FE	FV <sup>2</sup>	FE	FV <sup>2</sup>
KC-1-1	1	Sand A	Limestone	5.67	100	110	15,430	100	99	90	92	90	84	83	76	80	74	78	
KC-1-2			A	5.60	100	112	15,150	100	102	93	93	94	89	86	79	95	79	80	
KC-1-3				5.59	100	110	15,150	100	106	95	99	96	93	87	84	88	83	76	
KC-2-1	2	Sand B	Limestone	5.36	100	111	15,060	100	104	95	93	94	87	88	77	86	75	81	
KC-2-2			AA	5.34	100	109	15,060	100	102	94	88	90	85	81	76	76	74	60	
KC-2-3				5.34	100	108	15,060	100	104	97	95	98	90	90	78	89	78	81	
KC-3-1	3	Sand B	Limestone	5.39	100	88	14,125	100	74	73	46F*								
KC-3-2			B	5.36	100	88	14,045	100	68	72	48F								
KC-3-3				5.41	100	Broken at installation													
KC-4-1	4	Sand B	Limestone	5.34	100	108	14,620	100	112	99	105	99	88	93	82	92	76	85	
KC-4-2			C	5.34	100	107	14,535	100	113	98	108	104	92	96	86	96	83	93	
KC-4-3				5.40	100	105	14,795	100	109	100	100	100	89	94	79	89	80	83	
KC-5-1	5	Sand B	Limestone	5.16	100	112	15,430	100	114	98	108	105	104	103	101	85	99	69	
KC-5-2			D	5.14	100	114	15,530	100	114	98	112	100	107	103	101	104	102	95	
KC-5-3				5.15	100	111	15,530	100	113	98	110	102	108	103	100	**	102	73	
KC-6-1	6	Sand C	Limestone	5.84	100	111	15,335	100	116	99	112	105	111	108	106	104	109	79	
KC-6-2			D	5.83	100	111	15,335	100	117	101	113	105	111	108	106	109	109	108	
KC-6-3				5.81	100	112	15,245	100	117	101	115	106	113	106	107	112	106	112	

					1964-1971 Readings															
					735 Cycles 1964		898 Cycles 1965		1028 Cycles 1966		1184 Cycles 1967		1369 Cycles 1968		1523 Cycles 1969		1676 Cycles 1970		1845 Cycles 1971	
					$\frac{FE}{V}$	$\frac{FV^2}{V^2}$	$\frac{FE}{V}$	$\frac{FV^2}{V^2}$	$\frac{FE}{V}$	$\frac{FV^2}{V^2}$	$\frac{FE}{V}$	$\frac{FV^2}{V^2}$	$\frac{FE}{V}$	$\frac{FV^2}{V^2}$	$\frac{FE}{V}$	$\frac{FV^2}{V^2}$	$\frac{FE}{V}$	$\frac{FV^2}{V^2}$	$\frac{FE}{V}$	$\frac{FV^2}{V^2}$
KC-1-1	1	Sand A	Limestone	5.67	64	69	59	68	54	49	F									
KC-1-2			A	5.60	69	68	62	68	59	49	56	38	F	--						
KC-1-3				5.59	76	68	71	68	59	53	54	43	34F	32						
KC-2-1	2	Sand B	Limestone	5.36	65	--	71	--	63	--	56	--	F	--						
KC-2-2			AA	5.34	69	--	62	--	60	--	F									
KC-2-3				5.34	74	70	65	32	63	51	55	54	F	--						
KC-4-1	4	Sand B	Limestone	5.34	66	77	67	82	74	64	74	68	F	--						
KC-4-2			C	5.34	72	85	62	85	F											
KC-4-3				5.40	66	83	61	82	F											
KC-5-1	5	Sand B	Limestone	5.16	97	89	108	91	110	89	103	91	94	88	92	84	96	77	96	64
KC-5-2			D	5.14	97	99	78	101	86	88	82	90	76	85	74	82	82	78	84	59
KC-5-3				5.15	98	94	94	101	94	83	94	67	92	89	90	77	94	83	95	66
KC-6-1	6	Sand C	Limestone	5.84	102	98	101	110	101	87	97	98	97	101	97	89	99	86	97	71
KC-6-2			D	5.83	101	104	99	117	97	88	97	95	93	94	91	85	91	82	95	69
KC-6-3				5.81	104	99	102	120	100	89	100	98	98	99	94	92	96	88	98	75

-- Dashed lines in "FE<sup>2</sup>" column indicate end of specimen was too rough to obtain satisfactory reading.

\* F denotes specimen has failed.

\*\* A spurious reading was obtained on this beam in 1962 and was discarded.

(Revised August 1977)

Table 1-KCD (Continued)

Section 27

Beam No.	Mix- ture No.	Fine Aggregate	Coarse Aggregate	Cement Factor bags/ cu yd	Exposure Rack, Row 2 (W to E)											
					1972-						Readings					
					2002		2142		2278		2390		2536		2613	
					Cycles 1972		Cycles 1973		Cycles 1974		Cycles 1975		Cycles 1976		Cycles 1977	
					$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$
KC-5-1	5	Sand B	Limestone	5.16	96	66	98	79	94	82	88	70	92	*	84	
KC-5-2			D	5.14	NR†	79	88	87	88	81	84	66	78	*	76	
KC-5-3				5.15	74	65	93	83	93	90	93	107	85	*	81	
KC-6-1	6	Sand C	Limestone	5.84	95	87	101	94	93	98	97	121	89	96	89	91
KC-6-2			D	5.83	89	78	91	90	89	93	89	75	85	94	85	80
KC-6-3				5.81	96	79	96	98	92	93	90	77	88	85	86	92

† NR denotes a satisfactory reading was not obtained as specimen would not respond to flexural vibration.

(Sheet 2)

\* End of specimen too rough to obtain reading.  $\frac{1}{2}V^2$  data discontinued.

(Revised August 1977)  
Table 2-KCD (Continued)

Section 27

Exposure Rack, Row 2 (W to E)																
Beam No.	Mix- ture No.	Fine Aggregate	Coarse Aggregate	Cement Factor bags/ cu yd	1972-Readings											
					1809		1949		2085		2197		2343		2420	
					Cycles		Cycles		Cycles		Cycles		Cycles		Cycles	
					1972		1973		1974		1975		1976		1977	
					%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>
KC-8-1	8	Sand BB	Limestone	5.44	99	79	101	104	95	91	95	117	93	87	83	72
KC-8-2			F	5.44	NR††	55	NR	94	Failed							
KC-8-3				5.47	NR	68	NR	79	Failed							

†† Satisfactory reading not obtained due to deteriorated condition of specimen.

(Revised August 1977)

Table 3-KCD

Section 27

Mixture Data and Record of Testing of Concrete Beams, Kansas City District Aggregate Program1962- (Installed November 1962)

Exposure Rack, Row 2 (W to E)																		
1962-1967 Readings																		
Beam No.	Mix-ture No.	Fine Aggregate	Coarse Aggregate	Cement Replacement Material	Cement Factor bags/cu yd	0 Cycles, 1962		106 Cycles 1963		241 Cycles 1964		404 Cycles 1965		534 Cycles 1966		690 Cycles 1967		
						Pulse	Veloc											
						$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	
KC-13-1	13	Sand E	Limestone	None	5.47	100	15,150	100	117	101	102	100	102	110	100	101	94	104
KC-13-2			F		5.44	100	14,795	100	103	102	103	105	104	116	100	100	100	105
KC-13-3					5.46	100	15,150	100	103	102	103	99	101	112	99	95	93	104
KC-14-1	14	Sand E	Limestone	Fly ash*	5.13	100	14,535	100	102	104	102	104	103	130	101	98	101	105
KC-14-2			F		5.16	100	14,705	100	104	100	104	107	102	116	104	101	102	102
KC-14-3					5.13	100	14,535	100	104	105	102	102	100	109	98	98	98	106
KC-15-1	15	Sand E	Limestone	None	5.37	100	15,060	100	103	98	101	95	99	90	99	93	95	95
KC-15-2			C		5.36	100	15,060	100	102	105	101	95	97	101	99	93	91	95
KC-15-3					5.38	100	15,150	100	103	104	101	95	100	100	100	86	100	92

Beam No.	Mix- ture No.	Fine Aggregate	Coarse Aggregate	Cement Replacement Material	Cement Factor bags/cu yd	1968-1973 Readings											
						875 Cycles 1968		1029 Cycles 1969		1182 Cycles 1970		1351 Cycles 1971		1508 Cycles 1972		1648 Cycles 1973	
						$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$
						$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$
KC-13-1	13	Sand E	Limestone	None	5.47	98	100	98	94	96	90	94	75	82	87	88	101
KC-13-2			F		5.44	97	104	100	98	96	95	95	86	92	93	90	106
KC-13-3					5.46	97	100	99	94	97	90	96	75	89	75	93	87
KC-14-1	14	Sand E	Limestone	Fly ash*	5.13	101	107	99	102	97	99	97	74	101	86	101	88
KC-14-2			F		5.16	102	105	102	99	102	97	101	72	89	88	106	80
KC-14-3					5.13	100	105	98	99	98	95	106	68	100	--	122	86
KC-15-1	15	Sand E	Limestone	None	5.37	93	93	91	87	93	84	101	56	103	77	76	81
KC-15-2			C		5.36	80	85	80	76	84	75	F**	--	84	--	F	F
KC-15-3					5.38	84	81	84	70	82	68	85	--	84	--	F	F

Beam No.	Mix- ture No.	Fine Aggregate	Coarse Aggregate	Cement Replacement Material	Cement Factor bags/cu yd	1974- Readings							
						1784 Cycles 1974		1896 Cycles 1975		2042 Cycles 1976		2119 Cycles 1977	
						$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$
						$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$
KC-13-1	13	Sand E	Limestone	None	5.47	82	101	84	116	84	96	82	86
KC-13-2			F		5.44	88	104	84	122	88	98	84	90
KC-13-3					5.46	91	82	85	123	87	90	87	92
KC-14-1	14	Sand E	Limestone	Fly ash*	5.13	68	85	50	65	NR	NR	Failed	
KC-14-2			F		5.16	100	82	71	101	67	NR	Failed	
KC-14-3					5.13	113	80	Failed					
KC-15-1	15	Sand E	Limestone	None	5.37	63	76	Failed					
			C										

\* Fly ash content, 25 percent replacement by volume.

\*\* F denotes specimen has failed.

-- Dashed lines in " $\frac{1}{2}V^2$ " indicate that end of specimen was too rough to obtain satisfactory reading.

NR Denotes no satisfactory reading was obtained.

(Revised August 1977)

Table 4-KCD

Section 27

Mixture Data and Record of Testing of Concrete Beams, Kansas City District Aggregate Program

1963- (Installed December 1963)

Exposure Rack, Row 2 (W to E)																		
Beam No.	Mix-ture No.	Cement	Replace-ment Material	Fine Aggregate	Coarse Aggregate	Cement Factor bags/cu yd	1963-1967 Readings											
							0 Cycles, 1963			121 Cycles 1964		284 Cycles 1965		414 Cycles 1966		570 Cycles 1967		
							Pulse Veloc											
							$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	
KC-16-1	16	A	Fly ash*	Sand E	Limestone	6.25	100	14,535	100	104	105	104	98	106	104	106	122	
KC-16-2					F	6.27	100	14,705	100	104	105	105	95	103	105	103	114	
KC-16-3						6.26	100	14,620	100	103	105	104	101	100	106	100	114	
KC-17-1	17	B	None	Sand F	Gravel B	6.00	100	14,205	100	104	108	78	92	65	38	F		
KC-17-2						6.02	100	14,535	100	103	109	74	82	F				
KC-17-3						6.00	100	14,125	100	103	110	49F**	77					
KC-18-1	18	C	None	Sand G	Quartzite	5.73	100	14,705	100	102	107	100	100	102	111	102	117	
KC-18-2						5.77	100	15,150	100	102	102	102	98	104	109	106	113	
KC-18-3						5.74	100	15,060	100	102	100	104	98	104	108	104	115	

							1968-1973 Readings											
							755		909		1062		1231		1388		1528	
							Cycles		Cycles		Cycles		Cycles		Cycles		Cycles	
							1968		1969		1970		1971		1972		1973	
							$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$
KC-16-1	16	A	Fly ash*	Sand E	Limestone	6.25	104	114	108	107	106	104	108	87	104	95	100	99
KC-16-2					F	6.27	107	110	109	105	109	100	107	84	105	88	107	93
KC-16-3						6.26	104	111	108	105	106	101	NR†	88	108	95	104	88
KC-18-1	18	C	None	Sand G	Quartzite	5.73	102	116	106	107	106	105	104	84	100	84	98	80
KC-18-2						5.77	102	109	104	104	108	102	106	85	104	87	92	88
KC-18-3						5.74	104	109	106	99	110	108	107	81	83	90	100	76

Beam No.	Mix-ture No.	Cement	Replace-ment Material	Fine Aggregate	Coarse Aggregate	Cement Factor bags/cu yd	1974- Readings							
							1974- Readings							
							1664 Cycles 1974		1776 Cycles 1975		1922 Cycles 1976		1999 Cycles 1977	
							$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$
KC-16-1	16	A	Fly ash*	Sand E	Limestone	6.25	98	106	98	137	94	79	90	98
KC-16-2					F	6.27	109	65	109	130	105	100	109	100
KC-16-3						6.26	104	68	104	125	104	90	104	NR
KC-18-1	18	C	None	Sand G	Quartzite	5.73	102	106	102	82	82	93	100	NR
KC-18-2						5.77	64	65	Failed					
KC-18-3						5.74	92	68	80	72	176	NR	Failed	

\* Fly ash content, 25 percent replacement by volume.

\*\* F denotes specimen has failed.

† NR denotes satisfactory reading was not obtained as specimen would not respond to flexural vibration.

(Revised August 1977)

Table 5-KCD

Section 27

Mixture Data and Record of Testing of Concrete Beams, Kansas City District Aggregate Program

1969- (Installed May 1969)

Exposure Rack, Row 2 (W to E)																
Beam No.	Mix- ture No.	Batch No.*	Aggregates	Air Content %	Avg** 28-day Compressive Strength psi	1969-1972 Readings										
						Initial Laboratory Readings, 1969			0 Cycles 1969		153 Cycles 1970		322 Cycles 1971		479 Cycles 1972	
						Pulse Veloc										
						f/s			f/s		f/s		f/s		f/s	
						$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$
KC-19-1	19	1	Crushed limestone 1-1/2 in. max	4.9	3360	100	14,620	100	101	100	93	97	88	84	83	92
KC-19-2	19	2	Crushed limestone 1-1/2 in. max	5.0	3360	100	14,620	100	100	100	90	98	87	84	83	91
KC-19-3	19	3	Crushed limestone 1-1/2 in. max	4.7	3640	100	14,620	100	106	101	90	98	90	85	88	92
						1973- Readings										
						619 Cycles 1973		755 Cycles 1974		867 Cycles 1975		1013 Cycles 1976		1090 Cycles 1977		
						$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	$\frac{1}{2}E$	$\frac{1}{2}V^2$	
KC-19-1	19	1	Crushed limestone 1-1/2 in. max	4.9	3360	83	102	83	114	83	78	81	114	66	109	
KC-19-2	19	2	Crushed limestone 1-1/2 in. max	5.0	3360	82	94	82	114	79	77	74	110	79	104	
KC-19-3	19	3	Crushed limestone 1-1/2 in. max	4.7	3640	84	101	86	113	86	139	82	116	82	105	

\* The water-cement ratio of all three batches was 5.39 gal/bag or 0.49 by weight.  
 \*\* Average based on compressive strength of three 6- by 12-in. cylinders per batch.

(Revised August 1977)

Table 6-KCD

Section 27

Mixture Data and Record of Testing of Concrete Beams, Kansas City District Aggregate Program

1975- (Installed July 1974)

										Exposure Rack, Row 2 (W to E)							
Beam No.	Mix- ture No.	Batch No.*	Aggregates	Air Content %	Avg** 28-day Compres- sive Strength psi	Initial Laboratory		1974- Readings									
						Readings, 1974		112		258		335					
						Pulse Veloc		Cycles		Cycles		Cycles					
						1975		1976		1976		1977					
						%E	fps	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>			
KC-20-1	20	1	Crushed limestone 1-1/2-in. max	5.0	3360	100	14,285	100	102	134	104	117	106	109			
KC-20-2	20	2	Crushed limestone 1-1/2-in. max	5.4	3280	100	14,370	100	107	129	105	107	110	101			
KC-20-3	20	3	Crushed limestone 1-1/2-in. max	5.3	3260	100	14,285	100	106	131	108	115	113	102			

\* The water-cement ratio of all three batches was 5.34 gal/cwt or 0.445 by wt.

\*\* Average based on compressive strength of three 6- by 12-in. cylinders per batch.

(Revised August 1977)

Table 7-KCD

Section 27

Mixture Data and Record of Testing of Concrete Beams, Kansas City District Aggregate Program

1975- (Installed July 1974)

Beam No.	Mix- ture No.	Batch No.*	Aggregates	Air Content %	Avg** 28-day Compre- sive Strength psi	Exposure Rack, Row 2 (W to E)									
						Initial Laboratory			Readings						
						Readings, 1974			112		258		335		
						Pulse Veloc			Cycles		Cycles		Cycles		
						1975			1976		1977				
						%E	fps	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	
KC-21-1	21	1	Crushed limestone 1-1/2-in. max	5.0	4600	100	14,795	100	102	134	106	114	104	104	
KC-20-2	21	2	Crushed limestone 1-1/2-in. max	4.9	5150	100	14,620	100	101	132	107	114	109	106	
KC-21-3	21	3	Crushed limestone 1-1/2-in. max	5.1	4930	100	14,535	100	102	139	106	116	106	105	

\* The water-cement ratio of all three batches was 5.28 gal/cwt or 0.44 by wt.

\*\* Average based on compressive strength of three 6- by 12-in. cylinders per batch.

Eufaula Dam Aggregates Study

In October 1958, three concrete cubes (8 cu ft) were installed at half-tide elevation on the beach at Treat Island as part of a program being conducted by the Tulsa District, CE, to develop information about the aggregates to be used in Eufaula Dam. These aggregates were from the Tulsa District. The cubes were fabricated at the Southwestern Division Laboratory, Dallas, Tex.

The cubes were made of air-entrained concrete, admixture Z being the air-entraining admixture; type II cement was the cementing medium. The aggregates were a natural sand fine aggregate and a crush stone coarse aggregate. Two cubes contain 6-in. maximum size aggregate, the other contains 3-in. maximum size aggregate. All cubes were fabricated in August 1958.

Table 1-ED lists these specimens and gives their exposure record along with pertinent mixture data.

(Revised August 1977)

Table 1-ED

Section 28

Mixture Data and Record of Testing of Concrete Cubes, Eufaula Dam Aggregate Study1958- (Installed October 1958)

Beach Row 1 (W to E)

1958-1965 Readings														
Cube No.	Coarse Aggregate		Air %	Water-Cement Ratio gal/bag	Theo Cement Factor bags/cu yd	0 Cycles, 1958		150 Cycles 1959	220 Cycles 1960	361 Cycles 1961	451 Cycles 1962	557 Cycles 1963	692 Cycles 1964	855 Cycles 1965
	Maximum Size in.	Description				Pulse Veloc								
							fps	$\%V^2$	$\%V^2$	$\%V^2$	$\%V^2$	$\%V^2$	$\%V^2$	$\%V^2$
1	6	Poor	5.4	4.97	4.0	14,450	100	95	101	96	100	102	110	113
2	6	Random	5.9	4.85	4.0	14,650	100	95	100	100	104	107	110	107
3	3	Random	5.7	5.30	4.0	14,075	100	95	103	99	102	108	111	112
1966-1973 Readings														
						985 Cycles 1966	1141 Cycles 1967	1326 Cycles 1968	1480 Cycles 1969	1633 Cycles 1970	1802 Cycles 1971	1959 Cycles 1972	2099 Cycles 1973	
						$\%V^2$	$\%V^2$	$\%V^2$	$\%V^2$	$\%V^2$	$\%V^2$	$\%V^2$	$\%V^2$	$\%V^2$
1	6	Poor	5.4	4.97	4.0	90	112	105	96	94	85	84	*	
2	6	Random	5.9	4.85	4.0	92	107	110	99	94	89	82	*	
3	3	Random	5.7	5.30	4.0	97	114	109	100	96	97	95	*	
1974- Readings														
						2235 Cycles 1974	2347 Cycles 1975	2493 Cycles 1976	2570 Cycles 1977					
						$\%V^2$	$\%V^2$	$\%V^2$	$\%V^2$					
1	6	Poor	5.4	4.97	4.0	94	88	92	97					
2	6	Random	5.9	4.85	4.0	115	109	108	93					
3	3	Random	5.7	5.30	4.0	109	99	96	93					

\* Equipment malfunctioned in 1973.

Alkali-Aggregate Reactivity Investigation

The purpose of this investigation is to determine the effect on alkali-aggregate reactivity of varying amounts of  $C_3A$  (tricalcium aluminate) in high-alkali and low-alkali cements in concrete specimens exposed to sea water at St. Augustine, Fla.

1955 Installations

In August 1955, 72 concrete beams (6 by 6 by 30 in.) were installed on the exposure rack at St. Augustine. In September 1955, 36 concrete beams (6 by 6 by 30 in.) were installed outdoors at the Waterways Experiment Station Suboffice, Jackson, Miss. The beams installed at Jackson were controls for those installed at St. Augustine. The concrete was air-entrained, and had a water-cement ratio of 0.5 (by wt), a slump of  $2-1/2 \pm 1/2$  in., and an air content of  $5.0 \pm 0.5\%$ . Cement factors were in the range of 4.5 to 5.8 bags per cu yd. Twelve concrete combinations were represented, in which two fine aggregates, three coarse aggregates (maximum size,  $1-1/2$  in.), two pozzolans, two high-alkali cements, and two low-alkali cements were used. Nine beams represented each of the 12 combinations (six beams at St. Augustine and three at Jackson).

Table 1-AA lists the specimens and gives their exposure record along with other pertinent information.

In November 1957, two of the specimens exposed at St. Augustine were returned to the laboratory for study (specimens 1823 and 1850). The findings were:

Beam 1823: Showed evidence of slight alkali-aggregate reaction; no sign that this had been damaging to the concrete.

Beam 1850: Showed evidence of heavy alkali-aggregate reaction and of heavy sulfate attack. The effects of this had been damaging to the concrete.

1956 Installations

In August 1956, 36 concrete beams (6 by 6 by 30 in.) were installed

on the exposure rack at St. Augustine and 18 concrete beams (6 by 6 by 30 in.) were installed outdoors at the WES Suboffice, Jackson, Miss. The beams installed at Jackson were controls for those installed at St. Augustine. The concrete was air-entrained and had a water-cement ratio of 0.5 (by wt), a slump of  $2-1/2 \pm 1/2$  in., and an air content of  $5.0 \pm 0.5\%$ . Cement factors were in the range of 4.5 to 5.8 bags per cu yd. Six concrete combinations were represented, in which two cement replacement materials, one high-alkali cement, one low-alkali cement, one fine aggregate, and one coarse aggregate (maximum size,  $3/4$  in.) were used. These six combinations represented a repeat of two of those included in the 1955 group plus each of these with the inclusion of each of two pulverized water-quenched iron blast furnace slags used as cement replacement materials. Nine beams represented each of the six combinations (six beams at St. Augustine and three beams at Jackson).

Table 2-AA lists the specimens and gives their exposure record along with other pertinent information.

In August 1971, 15 beams (9 from 1955 installation and 6 from 1956 installation) were returned to the laboratory for study. The testing and installation of specimens at St. Augustine were discontinued after the 1970 inspection.

(Revised Aug 1964)

Table 1-AA

Section 29

## Record of Testing of Concrete Beams, Alkali-aggregate Reactivity Investigation

1955- (Installed August and September 1955)

1955-1964 Readings																
Beam No.	Cement	Replacement Material* (Pozzolan)	Fine Aggregate	Coarse* Aggregate	1955		1956		1958		1960		1962		1964	
					Pulse Veloc	$\Delta V^2$	$\Delta E$	$\Delta V^2$	$\Delta E$	$\Delta V^2$	$\Delta E$	$\Delta V^2$	$\Delta E$			
Beams Installed at St. Augustine, Fla., Aug 1955																
1823	RC 331	None	Nat sand	Nat gravel	100	14,620	100	104	117	**						
1824	high alkali			+ quartz-	100	14,970	100	103	99	115	96	64	98	Failed		
1826	low C <sub>3</sub> A			ite (5%)	100	14,620	100	102	100	126	100	††				
1827					100	14,535	100	104	104	121	102	92	92	Failed		
1829					100	14,880	100	104	99	125	90	††				
1830					100	15,060	100	103	98	131	97	106	93	56	82	Failed
1832	RC 333	None	Nat sand	Nat gravel	100	14,370	100	107	106	131	109	116	111	111	123	109
1833	low alkali			+ quartz-	100	14,370	100	109	109	132	109	112	111	108	120	106
1835	low C <sub>3</sub> A			ite (5%)	100	14,450	100	107	105	117	109	112	114	106	117	106
1836					100	15,060	100	107	102	120	102	115	108	109	116	107
1838					100	15,060	100	108	98	119	102	116	106	109	112	107
1839					100	14,880	100	108	101	120	102	115	108	108	113	106
1841	RC 333	None	Limestone sand	Limestone	100	14,880	100	109	112	120	115	119	121	113	122	110
1842	low alkali				100	15,150	100	109	108	120	112	119	118	115	128	112
1844	low C <sub>3</sub> A				100	14,975	100	112	112	124	116	117	119	105	127	103
1845					100	14,705	100	111	110	132	113	118	122	111	134	107
1847					100	14,535	100	114	111	146	114	119	122	118	125	118
1848					100	14,535	100	113	114	139	117	120	123	114	137	115
1850	RC 332	None	Nat sand	Nat gravel	100	14,125	100	69	87	**						
1851	high alkali			+ quartz-	100	14,370	100	66	83	124	36	Failed				
1853	high C <sub>3</sub> A			ite (5%)	100	14,795	100	68	87	†						
1854					100	14,620	100	86	89	110	39	Failed				
1856					100	14,620	100	67	78	77	23	Failed				
1857					100	14,620	100	56	79	73	26	Failed				
1859	RC 332	None	Limestone sand	Limestone	100	15,060	100	105	109	126	106	110	113	105	122	122
1860	high alkali				100	14,880	100	105	109	120	117	110	115	99	124	107
1862	high C <sub>3</sub> A				100	15,245	100	106	105	126	110	110	112	106	121	104
1863					100	14,795	100	105	109	124	113	112	113	108	122	108
1865					100	14,620	100	105	105	123	111	108	113	104	127	108
1866					100	14,620	100	105	109	124	109	119	120	114	132	115
1868	RC 334	None	Limestone sand	Limestone	100	14,705	100	108	114	125	117	107	116	103	122	103
1869	low alkali				100	14,205	100	110	115	130	118	119	120	114	129	114
1871	high C <sub>3</sub> A				100	14,620	100	110	113	126	116	116	120	112	128	113
1872					100	14,880	100	110	113	128	115	117	118	111	131	117
1874					100	14,970	100	108	109	127	112	118	116	114	126	114
1875					100	14,880	100	108	109	131	112	117	115	112	125	112
1877	RC 331	None	Nat sand	Nat gravel	100	15,060	100	104	99	125	101	110	104	105	109	110
1878	high alkali				100	14,705	100	103	89	115	101	109	109	102	114	102
1880	low C <sub>3</sub> A				100	14,795	100	103	100	119	100	108	105	107	113	103
1881					100	14,795	100	104	100	121	100	110	106	105	113	108
1883					100	14,970	100	107	98	121	98	108	105	104	109	108
1884					100	14,970	100	105	99	118	100	111	105	107	106	107
1886	RC 332	None	Nat sand	Nat gravel	100	14,285	100	105	97	115	109	107	105	103	106	105
1887	high alkali				100	14,450	100	104	98	113	97	106	104	107	107	104
1889	high C <sub>3</sub> A				100	14,370	100	103	98	112	100	111	106	107	110	109
1890					100	14,535	100	104	99	117	98	111	106	108	113	108
1892					100	14,880	100	104	98	114	97	107	101	103	105	106
1893					100	14,620	100	106	98	116	99	104	102	102	109	102
1895	RC 331	Shale 30%	Nat sand	Nat gravel	100	13,735	100	115	102	131	112	107	109	102	119	104
1896	high alkali			+ quartz-	100	13,810	100	114	102	131	105	125	109	119	116	123
1898	low C <sub>3</sub> A			ite (5%)	100	14,125	100	109	99	122	102	119	110	113	114	113
1899					100	14,370	100	110	98	123	101	121	107	113	111	119
1901					100	13,890	100	113	99	129	110	133	110	125	113	119
1902					100	14,125	100	110	99	127	102	121	106	115	112	122
1904	RC 331	Fly ash 20%	Nat sand	Nat gravel	100	14,705	100	106	97	122	94	114	106	107	112	102
1905	high alkali			+ quartz-	100	14,705	100	107	98	122	101	115	107	108	113	106
1907	low C <sub>3</sub> A			ite (5%)	100	14,705	100	108	105	106	101	96	110	93	114	92
1908					100	14,795	100	104	102	116	102	110	107	103	114	107
1910					100	14,880	100	107	98	122	100	112	105	107	115	109
1911					100	14,880	100	108	97	120	100	113	105	109	110	106

(Continued)

\* Percentages given are by volume of material replaced.

\*\* Returned to laboratory November 1957.

† Broken in handling 1958.

†† Broken in handling 1960.

(Sheet 1)

(Revised Sept 1966)  
Table 1-AA (Continued)

Section 29

					1955-1964 Readings											
Beam No.	Cement	Replacement Material (Pozzolan)	Fine Aggregate	Coarse Aggregate	1955		1956		1958		1960		1962		1964	
					Pulse Veloc f/s	$\%V^2$	$\%E$	$\%V^2$	$\%E$	$\%V^2$	$\%E$	$\%V^2$	$\%E$	$\%V^2$		
Beams Installed at St. Augustine, Fla., Aug 1955 (Continued)																
1913	RC 332	Shale 30%	Nat sand	Nat gravel	100	13,515	100	114	102	132	106	122	110	117	121	106
1914	high alkali			+ quartz-	100	13,515	100	111	103	130	106	124	113	115	117	104
1916	high C <sub>3</sub> A			ite (5%)	100	13,890	100	110	102	126	103	119	111	113	119	101
1917					100	13,890	100	113	103	124	105	118	110	113	115	101
1919					100	14,125	100	111	102	127	106	116	106	110	111	99
1920					100	14,285	100	112	97	130	100	120	105	115	112	97
1922	RC 332	Fly ash 20%	Nat sand	Nat gravel	100	14,535	100	107	100	75	92	F*	72			
1923	high alkali			+ quartz-	100	14,450	100	106	104	100	99	F	78			
1925	high C <sub>3</sub> A			ite (5%)	100	14,535	100	106	100	68	88	F	71			
1926					100	14,535	100	107	101	120	102	112	105	66	89	43F 58
1928					100	14,705	100	108	100	129	99	115	101	53	72	40F 46
1929					100	14,970	100	107	100	115	96	69	85	F	70	
Beams Installed at Jackson, Miss., Sept 1955																
1825	RC 331	None	Nat sand	Nat gravel	100	14,970	100	102	104	98	102	108	98	102	101	99
1828	high alkali			+ quartz-	100	14,795	100	105	104	111	100	107	98	100	100	98
1831	low C <sub>3</sub> A			ite (5%)	100	14,795	100	102	105	103	102	107	98	101	99	98
1834	RC 333	None	Nat sand	Nat gravel	100	14,205	100	104	101	107	108	109	105	103	106	105
1837	low alkali			+ quartz-	100	14,880	100	105	105	109	108	111	102	105	98	95
1840	low C <sub>3</sub> A			ite (5%)	100	14,620	100	106	109	110	106	112	105	106	102	101
1843	RC 333	None	Limestone	Limestone	100	14,880	100	105	112	108	115	110	116	103	109	110
1846	low alkali		sand		100	14,370	100	107	114	112	118	114	117	107	117	115
1849	low C <sub>3</sub> A				100	14,370	100	108	114	112	118	116	117	107	114	117
1852	RC 332	None	Nat sand	Nat gravel	100	14,125	100	104	106	107	105	108	100	104	102	99
1855	high alkali			+ quartz-	100	14,535	100	103	104	106	100	110	97	105	98	96
1858	high C <sub>3</sub> A			ite (5%)	100	14,535	100	100	104	104	101	104	99	98	98	96
1861	RC 332	None	Limestone	Limestone	100	14,880	100	102	109	108	113	111	113	103	109	115
1864	high alkali		sand		100	14,450	100	102	116	106	121	111	120	104	117	121
1867	high C <sub>3</sub> A				100	14,450	100	100	106	104	117	109	116	101	117	114
1870	RC 334	None	Limestone	Limestone	100	14,535	100	104	101	111	113	113	114	105	114	114
1873	low alkali		sand		100	14,450	100	105	113	112	117	114	114	106	116	113
1876	high C <sub>3</sub> A				100	14,705	100	104	107	111	110	113	110	104	112	111
1879	RC 331	None	Nat sand	Nat gravel	100	13,965	100	103	115	106	112	111	110	103	114	108
1882	high alkali				100	14,705	100	102	107	104	102	108	100	102	100	99
1885	low C <sub>3</sub> A				100	15,060	100	101	102	104	97	108	95	100	100	96
1888	RC 332	None	Nat sand	Nat gravel	100	14,125	100	103	107	107	100	110	98	101	105	101
1891	high alkali				100	13,890	100	104	111	109	105	111	100	104	107	101
1894	high C <sub>3</sub> A				100	14,620	100	103	101	105	98	107	94	101	96	93
1897	RC 331	Shale 30%	Nat sand	Nat gravel	100	13,660	100	95	102	103	98	106	94	101	102	99
1900	high alkali			+ quartz-	100	13,515	100	98	106	107	102	110	100	103	104	101
1903	low C <sub>3</sub> A			ite (5%)	100	13,735	100	93	101	100	99	105	96	98	101	98
1906	RC 331	Fly ash 20%	Nat sand	Nat gravel	100	14,535	100	96	106	102	101	106	107	98	101	100
1909	high alkali			+ quartz-	100	14,045	100	99	112	104	107	108	108	100	108	107
1912	low C <sub>3</sub> A			ite (5%)	100	14,705	100	94	102	99	100	103	100	96	100	99
1915	RC 332	Shale 30%	Nat sand	Nat gravel	100	13,160	100	93	103	102	103	107	104	100	105	102
1918	high alkali			+ quartz-	100	13,890	100	99	101	108	100	110	99	103	102	99
1921	high C <sub>3</sub> A			ite (5%)	100	13,515	100	96	102	103	103	105	95	98	104	98
1924	RC 332	Fly ash 20%	Nat sand	Nat gravel	100	14,205	100	97	101	103	105	107	102	99	106	105
1927	high alkali			+ quartz-	100	14,795	100	101	107	106	99	104	100	98	101	100
1930	high C <sub>3</sub> A			ite (5%)	100	14,705	100	96	104	104	99	115	98	100	100	99

\* F denotes specimen has failed.

(Revised Sept 1970)

Table 1-AA (Continued)

Section 29

Beam No.	Cement	Replacement Material (Pozzolan)	Fine Aggregate	Coarse Aggregate	1966-1970 Readings					
					1966		1968		1970	
					$\bar{E}$	$\bar{V}^2$	$\bar{E}$	$\bar{V}^2$	$\bar{E}$	$\bar{V}^2$
Beams Installed at St. Augustine, Fla., Aug 1955										
1832	RC 333	None	Nat sand	Nat gravel	109	121	109	110	109	109
1833	low alkali			+ quartz-	108	123	110	111	110	105
1835	low C <sub>3</sub> A			ite (5%)	107	125	108	111	108	107
1836					107	119	113	104	113	108
1838					107	120	103	103	103	101
1839					108	119	112	105	112	106
1841	RC 333	None	Limestone sand	Limestone	101	133	99	114	99	120
1842	low alkali				114	126	113	117	113	115
1844	low C <sub>3</sub> A				101	132	105	111	105	116
1845					111	134	115	116	117	119
1847					115	134	116	119	116	119
1848					113	137	112	119	112	116
1859	RC 332	None	Limestone sand	Limestone	103	138	105	109	103	105
1860	high alkali				103	126	101	113	101	109
1862	high C <sub>3</sub> A				103	123	108	108	106	105
1863					106	122	108	112	108	110
1865					104	127	102	109	104	112
1866					114	131	119	122	119	117
1868	RC 334	None	Limestone sand	Limestone	99	119	103	112	99	105
1869	low alkali				116	134	114	118	114	117
1871	high C <sub>3</sub> A				113	133	111	117	111	114
1872					111	129	111	115	111	118
1874					114	125	121	113	121	113
1875					112	127	117	111	117	116
1877	RC 331	None	Nat sand	Nat gravel	106	113	110	101	112	105
1878	high alkali				103	116	99	107	99	108
1880	low C <sub>3</sub> A				105	116	105	106	105	107
1881					105	105	104	108	104	107
1883					105	111	110	101	108	92
1884					107	107	106	102	110	95
1886	RC 332	None	Nat sand	Nat gravel	105	111	103	106	105	100
1887	high alkali				108	110	115	103	117	99
1889	high C <sub>3</sub> A				105	113	109	105	111	99
1890					106	114	108	108	108	103
1892					104	111	102	99	102	101
1893					101	112	102	101	102	105
1895	RC 331	Shale 30%	Nat sand	Nat gravel	104	119	104	110	104	110
1896	high alkali			+ quartz-	124	118	126	109	126	106
1898	low C <sub>3</sub> A			ite (5%)	114	115	115	107	113	103
1899					110	118	112	102	110	98
1901					134	120	133	113	130	108
1902					118	114	123	106	118	99
1904	RC 331	Fly ash 20%	Nat sand	Nat gravel	112	112	108	104	108	100
1905	high alkali			+ quartz-	109	118	106	104	106	101
1907	low C <sub>3</sub> A			ite (5%)	94	113	90	107	87	100
1908					107	112	104	104	106	98
1910					111	113	111	104	111	100
1911					110	111	105	103	105	99
1913	RC 332	Shale 30%	Nat sand	Nat gravel	121	120	126	110	129	108
1914	high alkali			+ quartz-	118	116	119	110	119	109
1916	high C <sub>3</sub> A			ite (5%)	115	117	114	109	114	107
1917					113	115	115	106	115	106
1919					113	114	115	103	111	97
1920					113	110	120	103	120	100

(Continued)

(Sheet 3)

(Revised Sept 1970)

Table 1-AA (Concluded)

Section 29

Beam No.	Cement	Replacement Material (Pozzolan)	Fine Aggregate	Coarse Aggregate	1966-1970 Readings					
					1966		1968		1970	
					$\frac{E}{V}$	$\frac{V}{V^2}$	$\frac{E}{V}$	$\frac{V}{V^2}$	$\frac{E}{V}$	$\frac{V}{V^2}$
Beams Installed at Jackson, Miss., Sept 1955										
1825	RC 331	None	Nat sand	Nat gravel	102	99	102	97	104	95
1828	high alkali			+ quartz-	100	95	102	95	103	94
1831	low C <sub>3</sub> A			ite (5%)	101	94	102	98	101	97
1834	RC 333	None	Nat sand	Nat gravel	103	92	104	105	107	101
1837	low alkali			+ quartz-	103	106	105	100	105	101
1840	low C <sub>3</sub> A			ite (5%)	105	100	106	101	107	100
1843	RC 333	None	Limestone	Limestone	104	101	104	109	107	109
1846	low alkali		sand		107	101	109	109	115	113
1849	low C <sub>3</sub> A				109	105	111	115	114	114
1852	RC 332	None	Nat sand	Nat gravel	104	89	104	97	108	97
1855	high alkali			+ quartz-	98	88	100	94	102	91
1858	high C <sub>3</sub> A			ite (5%)	95	85	98	97	100	91
1861	RC 332	None	Limestone	Limestone	105	113	107	117	108	112
1864	high alkali		sand		104	108	106	118	111	118
1867	high C <sub>3</sub> A				102	109	104	114	111	113
1870	RC 334	None	Limestone	Limestone	106	101	107	116	111	111
1873	low alkali		sand		107	110	108	114	111	114
1876	high C <sub>3</sub> A				104	106	105	106	112	104
1879	RC 331	None	Nat sand	Nat gravel	103	103	104	107	106	100
1882	high alkali				102	100	104	98	105	99
1885	low C <sub>3</sub> A				100	93	102	93	104	94
1888	RC 332	None	Nat sand	Nat gravel	101	96	103	99	105	97
1891	high alkali				102	100	102	99	106	99
1894	high C <sub>3</sub> A				98	92	100	93	102	90
1897	RC 331	Shale 30%	Nat sand	Nat gravel	94	85	98	89	108	89
1900	high alkali			+ quartz-	97	96	103	98	112	98
1903	low C <sub>3</sub> A			ite (5%)	94	83	98	95	105	93
1906	RC 331	Fly ash 20%	Nat sand	Nat gravel	98	90	100	100	101	98
1909	high alkali			+ quartz-	100	87	100	106	103	102
1912	low C <sub>3</sub> A			ite (5%)	97	98	96	98	98	93
1915	RC 332	Shale 30%	Nat sand	Nat gravel	96	94	99	102	104	100
1918	high alkali			+ quartz-	101	94	104	99	107	98
1921	high C <sub>3</sub> A			ite (5%)	93	93	96	97	103	94
1924	RC 332	Fly ash 20%	Nat sand	Nat gravel	99	106	100	102	103	102
1927	high alkali			+ quartz-	100	102	101	99	104	99
1930	high C <sub>3</sub> A			ite (5%)	98	98	98	97	102	97

(Revised Sept 1970)

Table 2-AA

Section 29

## Record of Testing of Concrete Beams, Alkali-Aggregate Reactivity Investigation

1956- (Installed August 1956)

Fine aggregate, limestone sand

Coarse aggregate, limestone (3/4-in. maximum size)

			1956-1970 Readings																	
Beam No.	Cement	Replacement Material*	1956		1958		1960		1962		1964		1966		1968		1970			
			Pulse Veloc fps	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>	%E	%V <sup>2</sup>		
Beams Installed at St. Augustine, Fla.																				
2535	RC 332	None	100	15,245	100	113	109	115	115	109	116	107	106	105	112	107	109	108	103	
2536	high alkali		100	15,060	100	116	112	121	115	114	121	113	106	111	113	112	112	117	108	
2538	high C <sub>3</sub> A		100	14,795	100	111	106	117	114	110	117	106	105	104	110	115	106	117	109	
2539			100	14,795	100	112	109	117	112	110	162	120	146	103	143	114	134	107	128	98
2541			100	14,970	100	111	109	113	115	104	126	104	110	102	111	106	111	107	101	107
2542			100	15,060	100	111	104	111	113	105	121	107	102	103	121	101	106	101	107	
2544	RC 334	None	100	15,430	100	122	109	122	110	111	118	111	103	109	127	111	109	111	111	
2545	low alkali		100	15,335	100	115	112	121	110	114	118	114	105	113	81	112	112	114	111	
2547	high C <sub>3</sub> A		100	14,620	100	114	113	115	119	109	123	107	107	103	120	101	115	103	107	
2548			100	14,705	100	128	99	115	129	106	122	106	107	106	123	110	109	110	108	
2550			100	15,060	100	115	115	123	116	108	122	108	99	108	147	110	111	112	109	
2551			100	15,060	100	114	116	122	116	107	122	112	109	110	135	112	111	112	103	
2553	RC 332	RC 198	100	15,925	100	111	108	122	108	109	119	114	106	112	143	112	108	112	103	
2554	high alkali	blast-furnace	100	15,925	100	113	107	130	111	115	121	111	106	111	145	118	107	118	104	
2556	high C <sub>3</sub> A	slag 40%	100	15,530	100	115	109	128	111	109	120	114	106	113	144	114	105	116	101	
2557			100	15,625	100	111	108	124	111	111	117	109	105	109	144	109	107	109	100	
2559			100	15,430	100	113	108	127	111	109	120	111	106	110	131	111	107	109	103	
2560			100	15,430	100	140	101	113	109	113	121	113	103	111	124	111	106	109	102	
2562	RC 332	RC 216	100	15,335	100	150	105	123	100	114	120	118	104	114	123	114	108	114	111	
2563	high alkali	blast-furnace	100	15,335	100	147	105	114	103	114	121	110	104	114	123	112	108	112	110	
2565	high C <sub>3</sub> A	slag 40%	100	15,335	100	113	109	130	105	112	117	108	106	109	119	108	107	106	104	
2566			100	15,430	100	123	105	126	111	117	117	110	108	110	117	112	107	110	103	
2568			100	15,060	100	114	108	127	113	109	118	109	107	111	125	113	111	111	108	
2569			100	14,970	100	119	108	128	115	112	122	112	109	113	121	116	111	114	109	
2571	RC 334	RC 198	100	15,530	100	127	103	132	111	117	115	114	103	114	114	112	106	110	104	
2572	low alkali	blast-furnace	100	15,625	100	127	104	133	111	114	118	118	106	119	132	118	106	116	103	
2574	high C <sub>3</sub> A	slag 40%	100	15,150	100	128	105	117	110	111	119	111	103	117	123	123	110	121	105	
2575			100	15,150	100	124	105	125	110	120	121	120	103	114	122	116	109	114	105	
2577			100	15,245	100	128	105	122	110	117	119	117	102	117	119	124	107	122	102	
2578			100	15,245	100	123	104	121	109	116	123	118	101	118	121	120	109	118	104	
2580	RC 334	RC 216	100	15,245	100	127	104	121	110	115	124	131	105	112	119	116	110	116	105	
2581	low alkali	blast-furnace	100	15,150	100	130	106	118	113	113	121	139	102	112	116	115	109	115	106	
2583	high C <sub>3</sub> A	slag 40%	100	15,150	100	130	106	123	110	114	119	112	106	117	121	115	109	113	102	
2584			100	15,060	100	123	105	122	112	108	119	102	106	107	119	106	109	102	102	
2586			100	15,150	100	130	105	116	113	110	113	110	103	114	142	113	110	109	98	
2587			100	15,060	100	129	106	119	113	113	116	113	107	116	120	117	109	115	106	
Beams Installed at Jackson, Miss.																				
2537	RC 332	None	100	14,970	100	106	109	113	104	104	112	104	110	105	116	107	108	109	109	
2540	high alkali		100	14,970	100	103	106	107	108	101	109	99	105	102	110	103	102	107	105	
2543	high C <sub>3</sub> A		100	15,150	100	104	105	110	105	103	106	101	105	104	107	105	102	107	102	
2546	RC 334	None	100	15,245	100	111	109	115	109	107	110	107	108	109	132	110	106	112	108	
2549	low alkali		100	14,705	100	110	106	114	106	105	109	105	106	106	106	107	102	109	105	
2552	high C <sub>3</sub> A		100	14,970	100	109	108	113	109	106	112	106	110	108	113	109	105	112	109	
2555	RC 332	RC 198	100	15,725	100	103	107	107	107	100	111	97	109	97	109	99	107	103	111	
2558	high alkali	blast-furnace	100	15,725	100	102	103	106	102	98	105	96	104	96	117	98	100	98	104	
2561	high C <sub>3</sub> A	slag 40%	100	15,430	100	100	108	106	108	97	108	96	106	97	117	98	106	100	108	
2564	RC 332	RC 216	100	15,335	100	104	109	108	108	99	112	98	109	98	127	100	104	102	106	
2567	high alkali	blast-furnace	100	15,150	100	104	109	104	108	96	109	98	108	100	123	100	105	102	108	
2570	high C <sub>3</sub> A	slag 40%	100	15,150	100	101	106	107	106	97	109	96	105	98	117	99	101	103	104	
2573	RC 334	RC 198	100	15,245	100	104	112	110	110	101	110	100	108	102	119	104	106	108	109	
2576	low alkali	blast-furnace	100	15,335	100	107	104	113	105	104	105	102	104	104	120	106	101	108	105	
2579	high C <sub>3</sub> A	slag 40%	100	14,880	100	104	115	110	112	100	113	100	110	100	126	103	109	107	110	
2582	RC 334	RC 216	100	15,430	100	107	107	113	104	102	105	102	100	102	116	104	99	106	104	
2585	low alkali	blast-furnace	100	15,060	100	106	110	113	109	102	110	102	105	103	118	104	102	106	106	
2588	high C <sub>3</sub> A	slag 40%	100	14,795	100	107	116	114	112	104	114	103	112	105	122	106	109	107	111	

\* Percentages given are by volume of material replaced.

Nonmetallic Waterstop Investigation

The purpose of this investigation is to evaluate the durability of nonmetallic waterstops of a variety of compositions, when exposed under different stress conditions, to different types and severity of exposure conditions.

The test specimens are rectangular pieces of nonmetallic waterstop material 1/16 to 3/8 in. thick. Pieces are either 6 by 6 in. or 3 by 6 in. in size. The specimens are exposed at four locations: Treat Island, Maine; St. Augustine, Fla.; Jackson, Miss. (indoors); and Jackson, Miss. (outdoors). Three stress conditions are represented:

- a. Unstressed; bolted on lumber stringer.
- b. Bent; bolted around lumber stringer (approximately 180°).
- c. Embedded; embedded across joint plane between two 6-in. concrete cubes and stressed to open up 1-in. gap in the joint plane. Wood blocks are inserted to maintain the waterstop in a stretched condition.

Treat Island Installations

In 1957 and 1958, 129 nonmetallic waterstop specimens were installed on the exposure rack at Treat Island as follows:

<u>Date</u>	<u>No. and Types of Specimens Installed</u>
May 1957	81 (27 embedded, 27 bent, and 27 unstressed)
Nov 1957	45 (15 embedded, 15 bent, and 15 unstressed)
Aug 1958	3 (1 embedded, 1 bent, and 1 unstressed)

Table 1-WS lists these specimens, identifies them as to type, manufacturer, and stress condition, and gives their exposure record. It should be noted that bent and unstressed specimens of the same material have the same specimen numbers. All remaining specimens were sent back to the concrete laboratory in 1973. Exposure was discontinued at that time.

St. Augustine Installations

In 1957 and 1958, 111 nonmetallic waterstops were installed on the

(Revised Sept 1969)

Table 1-WS

Section 30

## Record of Observations of Unstressed, Bent, and Embedded Specimens, Nonmetallic Waterstop Investigation

## Treat Island Exposure

1957- (Installed 1957 and 1958)

Exposure Rack, North Wall

				Condition of Unstressed Specimens, 1957-1965								
Specimen No.	Description	Manu- facturer	Date In- stalled	0	71	221	292	433	522	628	763	926
				Cycles 1957	Cycles 1958	Cycles 1959	Cycles 1960	Cycles 1961	Cycles 1962	Cycles 1963	Cycles 1964	Cycles 1965
NR-1-1	Natural rubber	A	May '57	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
NR-1-2				Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
NR-1-3				Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
NR-2-1	Natural rubber	B	Nov '57	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
NR-2-2	(3500-lb tensile			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
NR-2-3	strength)			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
SR-1-1	General service	A	May '57	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
SR-1-2	rubber			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
SR-1-3				Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
SR-2-1	General service	B	Nov '57	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
SR-2-2	rubber (2000-lb			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
SR-2-3	tensile strength)			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
SR-3-1	General service	B	Nov '57	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
SR-3-2	rubber (3000-lb			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
SR-3-3	tensile strength)			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
NEOR-1-1	Neoprene rubber	A	May '57	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
NEOR-1-2				Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
NEOR-1-3				Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
NEOR-2-1	Neoprene rubber	B	Nov '57	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
NEOR-2-2				Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
NEOR-2-3				Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
BUTYL-1-1	Butyl rubber	B	Nov '57	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
BUTYL-1-2				Sound	Sound	Sound	Lost*	Lost*	Sound	Sound	Sound	Sound
BUTYL-1-3				Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-2-1	Type IV standard	C	May '57	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-2-2	polyvinyl			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-2-3	chloride			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-2A-1	Type IV arctic	C	May '57	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-2A-2	polyvinyl			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-2A-3	chloride			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-3-1	Type V standard	C	May '57	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-3-2	polyvinyl			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-3-3	chloride			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-3A-1	Type V arctic	C	May '57	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-3A-2	polyvinyl			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-3A-3	chloride			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-4-1	Polyvinyl	A	May '57	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-4-2	chloride			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-4-3				Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-5-1	Polyvinyl	D	May '57	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-5-2	chloride			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-5-3				Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
				0	150	221	362	451	557	692	855	
				Cycles	Cycles	Cycles	Cycles	Cycles	Cycles	Cycles	Cycles	
				1958	1959	1960	1961	1962	1963	1964	1965	
PVC-9A(2)	Polyvinyl chloride	E	Aug '58	---	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound

(Continued)

\* This specimen presumably lost overboard in Sept 1959.

(Sheet 1)

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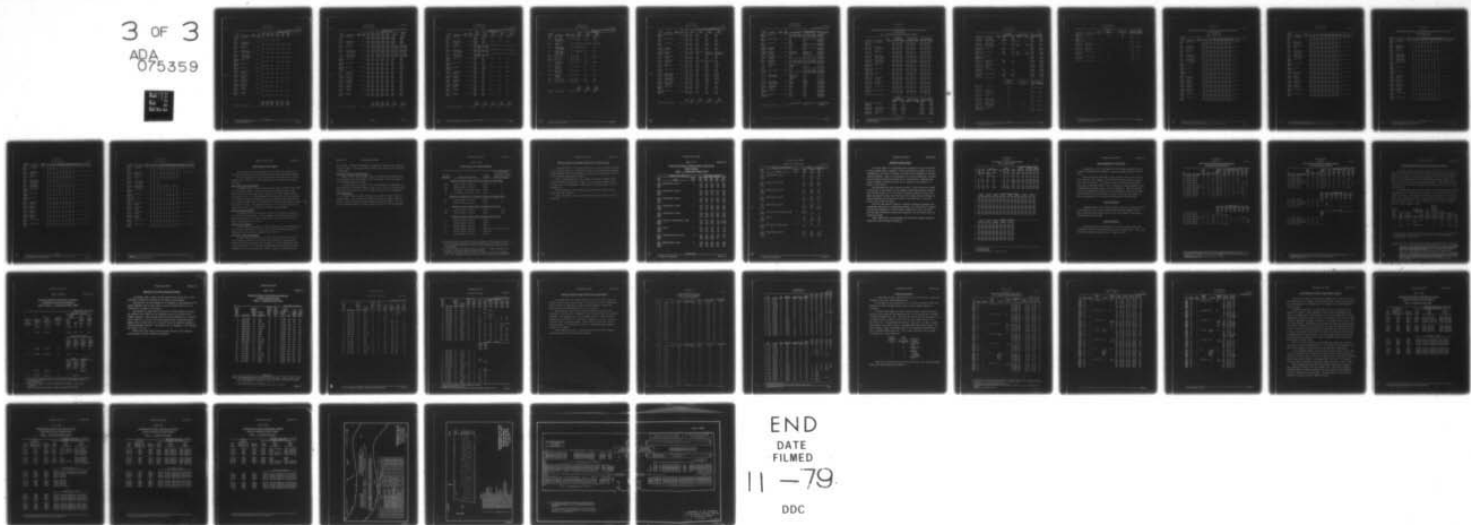
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INVESTIGATION OF PERFORMANCE OF CONCRETE AND CONCRETING MATERIA--ETC(U)  
AUG 77

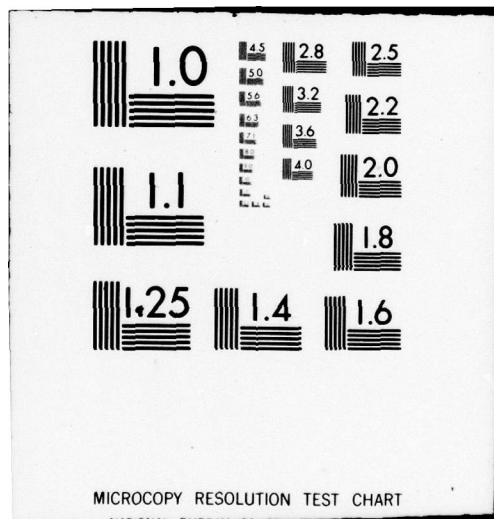
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(Revised Jan 1972)

Table 1-WS (Continued)

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Specimen No.	Description	Manu- facturer	Date In- stalled	Exposure Rack, North Wall					
				Condition of Unstressed Specimens, 1966-					
				1056 Cycles 1966	1212 Cycles 1967	1397 Cycles 1968	1551 Cycles 1969	1704 Cycles 1970	1873 Cycles 1971
NR-1-1	Natural rubber	A	May '57	†					
NR-1-2				†					
NR-1-3				Sound	Sound	Crazing	Crazing	†	
NR-2-1	Natural rubber	B	Nov '57	†					
NR-2-2	(3500-lb tensile strength)			†					
NR-2-3				Sound	Sound	Crazing	Crazing	Crazing	Crazing
SR-1-1	General service rubber	A	May '57	†					
SR-1-2				†					
SR-1-3				Sound	Sound	Crazing	Crazing	Crazing	Crazing
SR-2-1	General service rubber (2000-lb tensile strength)	B	Nov '57	†					
SR-2-2				†					
SR-2-3				Sound	Sound	Crazing	Crazing	Crazing	Crazing
SR-3-1	General service rubber (3000-lb tensile strength)	B	Nov '57	†					
SR-3-2				†					
SR-3-3				Sound	Sound	Crazing	Crazing	Crazing	Crazing
NEOR-1-1	Neoprene rubber	A	May '57	†					
NEOR-1-2				†					
NEOR-1-3				Sound	Sound	Sound	Crazing	Crazing	Crazing
NEOR-2-1	Neoprene rubber	B	Nov '57	†					
NEOR-2-2				†					
NEOR-2-3				Sound	Sound	Sound	Sound	Sound	Sound
BUTYL-1-1	Butyl rubber	B	Nov '57	†					
BUTYL-1-3				Sound	Sound	Sound	Sound	Sound	Sound
PVC-2-1	Type IV standard polyvinyl chloride	C	May '57	†					
PVC-2-2				†					
PVC-2-3				Sound	Sound††	Sound††	Sound††	Sound††	Sound
PVC-2A-1	Type IV arctic polyvinyl chloride	C	May '57	†					
PVC-2A-2				†					
PVC-2A-3				Sound	Sound	Sound	Sound	Sound	Sound
PVC-3-1	Type V standard polyvinyl chloride	C	May '57	†					
PVC-3-2				†					
PVC-3-3				Sound	Sound	Sound	Sound	Sound	Sound
PVC-3A-1	Type V arctic polyvinyl chloride	C	May '57	†					
PVC-3A-2				†					
PVC-3A-3				Sound	Sound	Sound	Sound	†	
PVC-4-1	Polyvinyl chloride	A	May '57	†					
PVC-4-2				†					
PVC-4-3				Sound	Sound	Sound	Sound	Sound	Sound
PVC-5-1	Polyvinyl chloride	D	May '57	†					
PVC-5-2				†					
PVC-5-3				Sound	Sound	Sound	Sound	Sound	Sound
PVC-9A(2)	Polyvinyl chloride	E	Aug '58	985 Cycles 1966	1141 Cycles 1967	1326 Cycles 1968	1480 Cycles 1969	1633 Cycles 1970	1802 Cycles 1971

(Continued)

† Returned to laboratory for tests.  
 †† This specimen has curled.

(Sheet 2)

(Revised Sept 1969)

Section 30

Table 1-WS (Continued)

Specimen No.	Description	Manu- facturer	Date In- stalled	Condition of Bent Specimens, 1957-1963						
				0 Cycles 1957	71 Cycles 1958	221 Cycles 1959	292 Cycles 1960	433 Cycles 1961	522 Cycles 1962	628 Cycles 1963
NR-1-1	Natural rubber	A	May '57	Sound	Crazing	Crazing	Crazing	Crazing	Crazing	Crazing
NR-1-2				Sound	Crazing	Crazing	Crazing	Crazing	Crazing	Crazing
NR-1-3				Sound	Crazing	Crazing	Crazing	Crazing	Crazing	Crazing
NR-2-1	Natural rubber (3500-lb tensile strength)	B	Nov '57	Sound	Crazing	Crazing	Crazing	Crazing	Crazing	Crazing
NR-2-2				Sound	Sound	Crazing	Crazing	Crazing	Crazing	Crazing
NR-2-3				Sound	Crazing	Crazing	Crazing	Crazing	Crazing	Crazing
SR-1-1	General service rubber	A	May '57	Sound	Crazing	Cracked	Cracked	Cracked	Badly cracked	Badly cracked
SR-1-2				Sound	Crazing	Cracked	Cracked	Cracked	Badly cracked	Badly cracked
SR-1-3				Sound	Crazing	Cracked	Cracked	Cracked	Badly cracked	Badly cracked
SR-2-1	General service rubber (2000-lb tensile strength)	B	Nov '57	Sound	Cracked	Cracked	Cracked	Cracked	Badly cracked	Badly cracked
SR-2-2				Sound	Cracked	Cracked	Cracked	Cracked	Badly cracked	Badly cracked
SR-2-3				Sound	Cracked	Cracked	Cracked	Cracked	Badly cracked	Badly cracked
SR-3-1	General service rubber (3000-lb tensile strength)	B	Nov '57	Sound	Sound	Cracked	Cracked	Cracked	Badly cracked	Badly cracked
SR-3-2				Sound	Sound	Cracked	Cracked	Cracked	Badly cracked	Badly cracked
SR-3-3				Sound	Sound	Cracked	Cracked	Cracked	Badly cracked	Badly cracked
NEOR-1-1	Neoprene rubber	A	May '57	Sound	Sound	Sound	Sound	Sound	Sound	Sound
NEOR-1-2				Sound	Sound	Sound	Sound	Sound	Sound	Sound
NEOR-1-3				Sound	Sound	Sound	Sound	Sound	Sound	Sound
NEOR-2-1	Neoprene rubber	B	Nov '57	Sound	Sound	Sound	Sound	Sound	Sound	Sound
NEOR-2-2				Sound	Sound	Sound	Sound	Sound	Sound	Sound
NEOR-2-3				Sound	Sound	Sound	Sound	Sound	Sound	Sound
BUTYL-1-1	Butyl rubber	B	Nov '57	Sound	Sound	Sound	Sound	Sound	Sound	Crazing
BUTYL-1-2				Sound	Sound	Sound	Sound	Sound	Sound	Crazing
BUTYL-1-3				Sound	Sound	Sound	Sound	Sound	Sound	Crazing
PVC-2-1	Type IV standard polyvinyl chloride	C	May '57	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-2-2				Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-2-3				Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-2A-1	Type IV arctic polyvinyl chloride	C	May '57	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-2A-2				Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-2A-3				Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-3-1	Type V standard polyvinyl chloride	C	May '57	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-3-2				Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-3-3				Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-3A-1	Type V arctic polyvinyl chloride	C	May '57	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-3A-2				Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-3A-3				Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-4-1	Polyvinyl chloride	A	May '57	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-4-2				Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-4-3				Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-5-1	Polyvinyl chloride	D	May '57	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-5-2				Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-5-3				Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-9A(2)	Polyvinyl chloride	E	Aug '58	---	0 Cycles 1958	150 Cycles 1959	221 Cycles 1960	362 Cycles 1961	451 Cycles 1962	557 Cycles 1963

(Continued)

(Sheet 3)

(Revised Sept 1969)

Table 1-WS (Continued)

Section 30

Exposure Rack, North Wall								
Specimen No.	Description	Manu- facturer	Date In- stalled	Condition of Bent Specimens, 1964-1968				
				763 Cycles 1964	926 Cycles 1965	1096 Cycles 1966	1212 Cycles 1967	1397 Cycles 1968
NR-1-1	Natural rubber	A	May '57	Crazing	Crazing	Crazing	Crazing	Cracked
NR-1-2				Crazing	Crazing	†		
NR-1-3				Crazing	Crazing	†		
NR-2-1	Natural rubber (3500-lb tensile strength)	B	Nov '57	Crazing	Crazing	Crazing	Crazing	Cracked
NR-2-2				Crazing	Crazing	†		
NR-2-3				Crazing	Crazing	†		
SR-1-1	General service rubber	A	May '57	Badly cracked	Badly cracked	Badly cracked	Badly cracked	Badly cracked
SR-1-2				Badly cracked	Badly cracked	†		
SR-1-3				Badly cracked	Badly cracked	†		
SR-2-1	General service rubber (2000-lb tensile strength)	B	Nov '57	Badly cracked	Badly cracked	Badly cracked	Badly cracked	Badly cracked, torn
SR-2-2				Badly cracked	Badly cracked	†		
SR-2-3				Badly cracked	Badly cracked	†		
SR-3-1	General service rubber (3000-lb tensile strength)	B	Nov '57	Badly cracked	Badly cracked	Badly cracked	Badly cracked	Badly cracked, torn
SR-3-2				Badly cracked	Badly cracked	†		
SR-3-3				Badly cracked	Badly cracked	†		
NEOR-1-1	Neoprene rubber	A	May '57	Sound	Sound	Sound	Sound	Sound
NEOR-1-2				Sound	Sound	†		
NEOR-1-3				Sound	Sound	†		
NEOR-2-1	Neoprene rubber	B	Nov '57	Sound	Sound	Sound	Sound	Sound
NEOR-2-2				Sound	Sound	†		
NEOR-2-3				Sound	Sound	†		
BUTYL-1-1	Butyl rubber	B	Nov '57	Crazing	Crazing	Crazing	Crazing	Crazing
BUTYL-1-2				Crazing	Crazing	†		
BUTYL-1-3				Crazing	Crazing	†		
PVC-2-1	Type IV standard polyvinyl chloride	C	May '57	Sound	Sound	Sound	Sound	Crazing
PVC-2-2				Sound	Sound	†		
PVC-2-3				Sound	Sound	†		
PVC-2A-1	Type IV arctic polyvinyl chloride	C	May '57	Sound	Sound	Sound	Sound	Sound
PVC-2A-2				Sound	Sound	†		
PVC-2A-3				Sound	Sound	†		
PVC-3-1	Type V standard polyvinyl chloride	C	May '57	Sound	Sound	Sound	Sound	Sound
PVC-3-2				Sound	Sound	†		
PVC-3-3				Sound	Sound	†		
PVC-3A-1	Type V arctic polyvinyl chloride	C	May '57	Sound	Sound	Sound	Sound	Sound
PVC-3A-2				Sound	Sound	†		
PVC-3A-3				Sound	Sound	†		
PVC-4-1	Polyvinyl chloride	A	May '57	Sound	Sound	Sound	Sound	Sound
PVC-4-2				Sound	Sound	†		
PVC-4-3				Sound	Sound	†		
PVC-5-1	Polyvinyl chloride	D	May '57	Sound	Sound	Sound	Sound	Sound
PVC-5-2				Sound	Sound	†		
PVC-5-3				Sound	Sound	†		
				692 Cycles 1964	855 Cycles 1965	985 Cycles 1966	1141 Cycles 1967	1326 Cycles 1968
PVC-9A(2)	Polyvinyl chloride	E	Aug '58	Sound	Sound	Sound	Sound	Sound

(Continued)

† Returned to laboratory in May 1966 for tests.

(Sheet 4)

(Revised Jan 1972)

Table 1-WS (Continued)

Section 30

Specimen No.	Description	Manu- facturer	In- stalled	Condition of Bent Specimens 1969-		
				1551 Cycles 1969	1704 Cycles 1970	1873 Cycles 1971
				Exposure Rack, North Wall		
NR-1-1	Natural rubber	A	May '57	Cracked	Cracked	Cracked
NR-2-1	Natural rubber (3500-lb tensile strength)	B	Nov '57	Cracked	Cracked	Cracked
SR-1-1	General service rubber	A	May '57	Badly cracked	Badly cracked	Badly cracked
SR-2-1	General service rubber (2000-lb tensile strength)	B	Nov '57	Badly cracked, Torn torn		Torn
SR-3-1	General service rubber (3000-lb tensile strength)	B	Nov '57	Badly cracked, Torn torn		Torn
NEOR-1-1	Neoprene rubber	A	May '57	Sound	Sound	Sound
NEOR-2-1	Neoprene rubber	B	Nov '57	Sound	Sound	Sound
BUTYL-1-1	Butyl rubber	B	Nov '57	Crazing	†	
PVC-2-1	Type IV standard polyvinyl chloride	C	May '57	Crazing	Crazing	Crazing
PVC-2A-1	Type IV arctic polyvinyl chloride	C	May '57	Sound	Sound	Sound
PVC-3-1	Type V standard polyvinyl chloride	C	May '57	Sound	Sound	Sound
PVC-3A-1	Type V arctic polyvinyl chloride	C	May '57	Sound	Sound	Sound
PVC-4-1	Polyvinyl chloride	A	May '57	Sound	Sound	Sound
PVC-5-1	Polyvinyl chloride	D	May '57	Sound	Sound	Sound
PVC-9A(2)	Polyvinyl chloride	E	Aug '58	Sound	Sound	Sound

† Returned to laboratory for tests.

(Sheet 5)

(Revised Sept 1969)

Table 1-WS (Continued)

Section 30

Specimen No.	Description	Manu- facturer	Date In- stalled	Condition of Embedded Specimens, 1957-1961				
				0 Cycles 1957	71 Cycles 1958	221 Cycles 1959	292 Cycles 1960	433 Cycles 1961
NEOR-1-15 NEOR-1-14 NEOR-1-13	Neoprene rubber	A	May '57	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound
PVC-4-7 PVC-4-6 PVC-4-5	Polyvinyl chloride	A	May '57	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound
NR-1-11 NR-1-12 NR-1-10	Natural rubber	A	May '57	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound	Crazing Sound Crazing	Crazing Sound Crazing
PVC-3A-25 PVC-3A-26 PVC-3A-27	Type V arctic polyvinyl chloride	C	May '57	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound
PVC-2A-24 PVC-2A-23 PVC-2A-22	Type IV arctic polyvinyl chloride	C	May '57	Sound Sound Sound	Badly torn Sound Sound	Completely torn Sound Sound	Completely torn Completely torn Completely torn	Completely torn Completely torn Completely torn
PVC-2-3 PVC-2-2 PVC-2-1	Type IV standard polyvinyl chloride	C	May '57	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound
PVC-3-6 PVC-3-5 PVC-3-4	Type V standard polyvinyl chloride	C	May '57	Sound Sound Sound	Sound Sound Sound	Concrete cracked Sound Sound	Concrete cracked Sound Sound	Sound Sound Sound
SR-1-18 SR-1-17 SR-1-16	General service rubber	A	May '57	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound	Crazing Crazing Sound	Crazing Crazing Sound
PVC-5-21 PVC-5-20 PVC-5-19	Polyvinyl chloride	D	May '57	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound
SR-3-105 SR-3-104 SR-3-103	General service rubber (3000-lb tensile strength)	B	Nov '57	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound	Crazing Crazing Crazing	Crazing Crazing Crazing
SR-2-102 SR-2-101 SR-2-100	General service rubber (2000-lb tensile strength)	B	Nov '57	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound	Crazing Crazing Crazing	Crazing Crazing Crazing
NR-2-99 NR-2-98 NR-2-97	Natural rubber (3500-lb tensile strength)	B	Nov '57	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound	Crazing Sound Sound	Crazing Sound Sound
NEOR-2-96 NEOR-2-95 NEOR-2-94	Neoprene rubber	B	Nov '57	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound
BUTYL-1-93 BUTYL-1-92 BUTYL-1-91	Butyl rubber	B	Nov '57	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound	Sound Sound Sound
PVC-9A(2)	Polyvinyl chloride	E	Aug '58	---	Sound	Sound	Sound	Sound
				Cycles 1957	0 Cycles 1958	150 Cycles 1959	221 Cycles 1960	362 Cycles 1961

(Continued)

(Sheet 6)

(Revised Sept 1969)

Table 1-WS (Concluded)

Section 30

Exposure Rack, Row 2 (W to E)

Specimen No.	Description	Manu- facturer	Date In- stalled	Condition of Embedded Specimens, 1962-1964		
				522 Cycles, 1962	628 Cycles, 1963	763 Cycles, 1964
NEOR-1-15	Neoprene rubber	A	May '57	Sound (concrete cracked)	Sound (concrete cracked)	Disintegrated
NEOR-1-14				Sound (concrete cracked)	Sound (concrete cracked)	Disintegrated
NEOR-1-13				Sound (concrete cracked)	Sound (concrete cracked)	Disintegrated
PVC-4-7	Polyvinyl chloride	A	May '57	Sound	Sound (concrete cracked)	Disintegrated
PVC-4-6				Sound	Sound	Disintegrated
PVC-4-5				Sound	Sound	Disintegrated
NR-1-11	Natural rubber	A	May '57	Crazing	Crazing	Disintegrated
NR-1-12				Sound	Sound (concrete cracked)	Disintegrated
NR-1-10				Crazing	Crazing	Disintegrated
PVC-3A-25	Type V arctic polyvinyl chloride	C	May '57	Sound	Sound (concrete cracked)	Disintegrated
PVC-3A-26				Sound	Sound	Disintegrated
PVC-3A-27				Sound	Sound	Disintegrated
PVC-2A-24	Type IV arctic polyvinyl chloride	C	May '57	Completely torn	Completely torn	Disintegrated
PVC-2A-23				Completely torn	Completely torn	Disintegrated
PVC-2A-22				Completely torn	Completely torn	Disintegrated
PVC-2-3	Type IV standard polyvinyl chloride	C	May '57	Sound	Sound (concrete cracked)	Disintegrated
PVC-2-2				Sound	Sound	Disintegrated
PVC-2-1				Sound (concrete cracked)	Sound (concrete cracked)	Disintegrated
PVC-3-6	Type V standard polyvinyl chloride	C	May '57	Sound (concrete cracked)	Sound (concrete cracked)	Disintegrated
PVC-3-5				Sound (concrete cracked)	Sound (concrete cracked)	Disintegrated
PVC-3-4				Sound (concrete cracked)	Sound (concrete cracked)	Disintegrated
SR-1-18	General service rubber	A	May '57	Crazing (concrete cracked)	Crazing	Disintegrated
SR-1-17				Crazing	Crazing	Disintegrated
SR-1-16				Sound	Sound (concrete cracked)	Disintegrated
PVC-5-21	Polyvinyl chloride	D	May '57	Sound	Sound (concrete cracked)	Disintegrated
PVC-5-20				Sound (concrete cracked)	Sound (concrete cracked)	Disintegrated
PVC-5-19				Sound	Sound (concrete cracked)	Disintegrated
SR-3-105	General service rubber (3000-lb tensile strength)	B	Nov '57	Crazing (concrete cracked)	Crazing	Disintegrated
SR-3-104				Crazing (concrete cracked)	Crazing	Disintegrated
SR-3-103				Crazing	Crazing	Disintegrated
SR-2-102	General service rubber (2000-lb tensile strength)	B	Nov '57	Crazing	Crazing	Disintegrated
SR-2-101				Crazing	Crazing	Disintegrated
SR-2-100				Crazing	Crazing	Disintegrated
NR-2-99	Natural rubber (3500-lb tensile strength)	B	Nov '57	Crazing	Crazing	Disintegrated
NR-2-98				Sound	Sound	Disintegrated
NR-2-97				Sound	Sound	Disintegrated
NEOR-2-96	Neoprene rubber	B	Nov '57	Sound	Sound	Disintegrated
NEOR-2-95				Sound	Sound	Disintegrated
NEOR-2-94				Sound	Sound	Disintegrated
BUTYL-1-93	Butyl rubber	B	Nov '57	Sound	Sound	Disintegrated
BUTYL-1-92				Sound	Sound	Disintegrated
BUTYL-1-91				Sound	Sound	Disintegrated
				451 Cycles, 1962	557 Cycles, 1963	692 Cycles, 1964
PVC-9A(2)	Polyvinyl chloride	E	Aug '58	Sound	Sound	Disintegrated

(Revised Sept 1969)

Table 2-WS

Section 30

Record of Observation of Unstressed, Bent, and Embedded Specimens, Nonmetallic Waterstop InvestigationSt. Augustine Exposure

1957- (Installed November 1957 Except Where Otherwise Indicated)

Specimen No.	Description	Manufac- turer	Condition of Unstressed Specimens, 1957-1960			Condition of Bent Specimens, 1957-1960			Condition of Embedded Specimens, 1957-1960		
			1957	1958	1960	1957	1958	1960	1957	1958	1960
NR-1-1 & 64	Natural rubber	A	Sound	Sound	Lost*	Sound	Sound	Lost	Sound	Sound	Sound
NR-1-2 & 65			Sound	Sound	Sound	Sound	Sound	Lost	Sound	Sound	Sound
NR-1-3 & 66			Sound	Sound	Sound	Sound	Sound	Lost	Sound	Sound	Sound
NR-2-1 & 82	Natural rubber (3500-lb tensile strength)	B	Sound	Sound	Sound	Sound	Sound	Lost	Sound	Sound	Sound
NR-2-2 & 83			Sound	Sound	Sound	Sound	Sound	Lost	Sound	Sound	Crazing
NR-2-3 & 84			Sound	Sound	Sound	Sound	Sound	Lost	Sound	Sound	Sound
SR-1-1 & 70	General service rubber	A	Sound	Sound	Sound	Sound	Sound	Lost	Sound	Sound	Sound
SR-1-2 & 71			Sound	Sound	Lost	Sound	Sound	Lost	Sound	Sound	Sound
SR-1-3 & 72			Sound	Sound	Sound	Sound	Sound	Lost	Sound	Sound	Sound
SR-2-1 & 85	General service rubber (2000-lb tensile strength)	B	Sound	Sound	Sound	Sound	Sound	Lost	Sound	Sound	Sound
SR-2-2 & 86			Sound	Sound	Sound	Sound	Sound	Lost	Sound	Sound	Crazing
SR-2-3 & 87			Sound	Sound	Sound	Sound	Sound	Cracked	Sound	Sound	Crazing
SR-3-1 & 88	General service rubber (3000-lb tensile strength)	B	Sound	Sound	Sound	Sound	Sound	Lost	Sound	Sound	Sound
SR-3-2 & 89			Sound	Sound	Sound	Sound	Sound	Cracked	Sound	Sound	Sound
SR-3-3 & 90			Sound	Sound	Lost	Sound	Sound	Cracked	Sound	Sound	Sound
NEOR-1-1 & 67	Neoprene rubber	A	Sound	Sound	Sound	Sound	Sound	Lost	Sound	Sound	Sound
NEOR-1-2 & 68			Sound	Sound	Sound	Sound	Sound	Lost	Sound	Sound	Sound
NEOR-1-3 & 69			Sound	Sound	Sound	Sound	Sound	Lost	Sound	Sound	Sound
NEOR-2-1 & 79	Neoprene rubber	B	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
NEOR-2-2 & 80			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
NEOR-2-3 & 81			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
BUTYL-1-1 & 76	Butyl rubber	B	Sound	Sound	Lost	Sound	Sound	Lost	Sound	Sound	Sound
BUTYL-1-2 & 77			Sound	Sound	Lost	Sound	Sound	Lost	Sound	Sound	Sound
BUTYL-1-3 & 78			Sound	Sound	Lost	Sound	Sound	Lost	Sound	Sound	Sound
PVC-2-1 & 55	Type IV standard polyvinyl chloride	C	Sound	Sound	Sound	Sound	Sound	Lost	Sound	Sound	Sound
PVC-2-2 & 56			Sound	Sound	Sound	Sound	Sound	Lost	Sound	Sound	Sound
PVC-2-3 & 57			Sound	Sound	Sound	Sound	Sound	Lost	Sound	Sound	†
PVC-3-1 & 58	Type V standard polyvinyl chloride	C	Sound	Sound	Lost	Sound	Sound	Lost	Sound	Sound	Sound
PVC-3-2 & 59			Sound	Sound	Lost	Sound	Sound	Lost	Sound	Sound	Sound
PVC-3-3 & 60			Sound	Sound	Lost	Sound	Sound	Lost	Sound	Sound	Sound
PVC-4-1 & 61	Polyvinyl chloride	A	Sound	Sound	Sound	Sound	Sound	Lost	Sound	Sound	Sound
PVC-4-2 & 62			Sound	Sound	Sound	Sound	Sound	Lost	Sound	Sound	Sound
PVC-4-3 & 63			Sound	Sound	Lost	Sound	Sound	Lost	Sound	Sound	Sound
PVC-5-1 & 73	Polyvinyl chloride	D	Sound	Sound	Sound	Sound	Sound	Lost	Sound	Sound	Sound
PVC-5-2 & 74			Sound	Sound	Sound	Sound	Sound	Lost	Sound	Sound	Sound
PVC-5-3 & 75			Sound	Sound	Sound	Sound	Sound	Lost	Sound	Sound	Sound
PVC-9A(2) & 91	Polyvinyl chloride	E	**	Sound	Lost	**	Sound	Lost	**	Sound	Sound

Specimen No.	Description	Manufac- turer	Condition of Unstressed Specimens, 1962-1964		Condition of Bent Specimens, 1962-1964		Condition of Embedded Specimens, 1962-1964	
			1962	1964	1962	1964	1962	1964
NR-1-1 & 64	Natural rubber	A					Crazing	Crazing
NR-1-2 & 65			Crazing		Crazing		Crazing	Crazing
NR-1-3 & 66			Crazing	Crazing			Crazing	Crazing
NR-2-1 & 82	Natural rubber (3500-lb tensile strength)	B	Crazing		Crazing		Crazing	Crazing
NR-2-2 & 83			Crazing	Crazing			Crazing	Crazing
NR-2-3 & 84			Crazing	Crazing			Crazing	Crazing
SR-1-1 & 70	General service rubber	A	Crazing		Crazing		Crazing	Crazing
SR-1-2 & 71							Crazing	Crazing
SR-1-3 & 72			Crazing	Crazing			Crazing	Crazing

(Continued)

\* Specimens marked "Lost" have disappeared from the exposure rack.

\*\* Installed Aug 1958.

† Specimen completely torn.

(Sheet 1)

(Revised Sept 1970)

Table 2-WS (Continued)

Section 30

Specimen No.	Description	Manufac- turer	Condition of Unstressed Specimens, 1962-1964		Condition of Bent Specimens, 1962-1964		Condition of Embedded Specimens, 1962-1964	
			1962	1964	1962	1964	1962	1964
SR-2-1 & 85	General service rubber (2000-lb tensile strength)	B	Cracked	Cracked			Crazing	Crazing
SR-2-2 & 86			Crazing	Crazing			Crazing	Crazing
SR-2-3 & 87			Crazing	Cracked	Cracked	Lost	Crazing	Crazing
SR-3-1 & 88	General service rubber (3000-lb tensile strength)	B	Cracked	Cracked			Sound	Sound
SR-3-2 & 89			Crazing	Cracked	Cracked	Cracked	Sound	Sound
SR-3-3 & 90					Cracked	Cracked	Sound	Sound
NEOR-1-1 & 67	Neoprene rubber	A	Sound	Sound			Crazing	Crazing
NEOR-1-2 & 68			Sound	Sound			Crazing	Crazing
NEOR-1-3 & 69			Sound	Sound			Crazing	Crazing
NEOR-2-1 & 79	Neoprene rubber	B	Sound	Sound	Sound	Sound	Crazing	Crazing
NEOR-2-2 & 80			Sound	Sound	Sound	Sound	Crazing	Crazing
NEOR-2-3 & 81			Sound	Sound	Cracked	Cracked	Crazing	Crazing
BUTYL-1-1 & 76	Butyl rubber	B					Crazing	Crazing
BUTYL-1-2 & 77							Crazing	Crazing
BUTYL-1-3 & 78							Crazing	Crazing
PVC-2-1 & 55	Type IV standard polyvinyl chloride	C	Sound	Lost			Crazing	Crazing
PVC-2-2 & 56			Sound	Lost			Crazing	Crazing
PVC-2-3 & 57			Sound	Lost			Crazing	Crazing
PVC-3-1 & 58	Type V standard polyvinyl chloride	C					Crazing	Crazing
PVC-3-2 & 59							Crazing	Crazing
PVC-3-3 & 60							Crazing	Crazing
PVC-4-1 & 61	Polyvinyl chloride	A	Sound	Sound			Crazing	Crazing
PVC-4-2 & 62			Sound	Sound			Crazing	Crazing
PVC-4-3 & 63							Crazing	Crazing
PVC-5-1 & 73	Polyvinyl chloride	D	Sound	Sound			Crazing	Crazing
PVC-5-2 & 74			Sound	Sound			Crazing	Crazing
PVC-5-3 & 75			Sound	Sound			Crazing	Crazing
PVC-9A(2) & 91	Polyvinyl chloride	E					Crazing	Crazing

Specimen No.	Description	Manufac- turer	Condition of Unstressed Specimens		Condition of Bent Specimens		Condition of Embedded Specimens, 1966-1970	
			1966		1966		1966	1966 and 1970
NR-1-1 & 64	Natural rubber	A					††	
NR-1-2 & 65			††				††	
NR-1-3 & 66			††				Crazing	Crazing†
NR-2-1 & 82	Natural rubber (3500-lb tensile strength)	B	††				††	
NR-2-2 & 83			††				††	
NR-2-3 & 84			††				Crazing	Crazing†
SR-1-1 & 70	General service rubber	A	††				††	
SR-1-2 & 71			††				††	
SR-1-3 & 72			††				Crazing	Crazing†
SR-2-1 & 85	General service rubber (2000-lb tensile strength)	B	††				††	
SR-2-2 & 86			††				††	
SR-2-3 & 87			††				Crazing	Crazing†
SR-3-1 & 88	General service rubber (3000-lb tensile strength)	B	††				††	
SR-3-2 & 89			††		Lost		††	
SR-3-3 & 90			††		Lost		Sound	Crazing†
NEOR-1-1 & 67	Neoprene rubber	A	††				††	
NEOR-1-2 & 68			††				††	
NEOR-1-3 & 69			††				Crazing	Crazing†

(Continued)

†† Returned to laboratory in June 1966 for tests.  
 † Exposure discontinued in 1970.

(Sheet 2)

(Revised Sept 1970)  
Table 2-WS (Concluded)

Section 30

Specimen No.	Description	Manufac- turer	Condition of Unstressed Specimens	Condition of Bent Specimens	Condition of Embedded Specimens, 1966-1970	
			1966	1966	1966	1968 and 1970
NEOR-2-1 & 79	Neoprene rubber	B	††	Lost	††	
NEOR-2-2 & 80			††	Lost	††	
NEOR-2-3 & 81			††	Lost	Crazing	Crazing*
BUTYL-1-1 & 76	Butyl rubber	B			††	
BUTYL-1-2 & 77					††	
BUTYL-1-3 & 78					Crazing	Crazing*
PVC-2-1 & 55	Type IV standard polyvinyl chloride	C			††	
PVC-2-2 & 56					††	
PVC-2-3 & 57					Crazing	Completely torn*
PVC-3-1 & 58	Type V standard polyvinyl chloride	C			††	
PVC-3-2 & 59					††	
PVC-3-3 & 60					Crazing	Crazing*
PVC-4-1 & 61	Polyvinyl chloride	A	††		††	
PVC-4-2 & 62			††		††	
PVC-4-3 & 63					Crazing	Crazing*
PVC-5-1 & 73	Polyvinyl chloride	D	††		††	
PVC-5-2 & 74			††		††	
PVC-5-3 & 75			††		Crazing	Crazing*
PVC-9A(2) & 91	Polyvinyl chloride	E			††	

†† Returned to laboratory in June 1966 for tests.  
\* Exposure discontinued in 1970.

(Revised Jan 1972)

Table 3-WS

Section 30

## Record of Observations of Unstressed and Bent Specimens, Nonmetallic Waterstop Investigation

## Jackson Indoor Exposure

1957- (Installed 1957)

WES Specimen No.	Description	Manu- facturer	Condition of Unstressed Specimens, 1957-										1970**									
			1957	1958	1959	1960	1962	1963	1964	1965	1966											
NR-1-1	Natural rubber	A	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound										
NR-1-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*											
NR-1-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*										
NR-2-1	Natural rubber (3500-lb tensile strength)	B	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound										
NR-2-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*										
NR-2-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*									
SR-1-1	General service rubber	A	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound										
SR-1-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*									
SR-1-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*								
SR-2-1	General service rubber (2000-lb tensile strength)	B	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound										
SR-2-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*								
SR-2-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*							
SR-3-1	General service rubber (3000-lb tensile strength)	B	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound										
SR-3-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*								
SR-3-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*							
NEOR-1-1	Neoprene rubber	A	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound										
NEOR-1-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*								
NEOR-1-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*							
NEOR-2-1	Neoprene rubber	B	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound										
NEOR-2-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*							
NEOR-2-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*						
BUTYL-1-1	Butyl rubber	B	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound										
BUTYL-1-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*							
BUTYL-1-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*						
PVC-2-1	Type IV standard polyvinyl chloride	C	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound										
PVC-2-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*						
PVC-2-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*					
PVC-2A-1	Type IV arctic polyvinyl chloride	C	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound										
PVC-2A-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*					
PVC-2A-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*				
PVC-3-1	Type V standard polyvinyl chloride	C	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound										
PVC-3-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*				
PVC-3-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*			
PVC-3A-1	Type V arctic polyvinyl chloride	C	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound										
PVC-3A-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*			
PVC-3A-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
PVC-4-1	Polyvinyl chloride	A	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound										
PVC-4-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
PVC-4-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*	
PVC-5-1	Polyvinyl chloride	D	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound										
PVC-5-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*	
PVC-5-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*

\* Removed from exposure in June 1966 for tests.

\*\* The condition of all of these specimens was the same in 1967, 1968, 1969, and 1970.

(Sheet 1)

(Revised Jan 1972)

Table 3-WS (Concluded)

Section 30

WES Specimen No.	Description	Manu- facturer	Condition of Bent Specimens, 1957-										
			1957	1958	1959	1960	1962	1963	1964	1965	1966	1970**	1971
NR-1-1	Natural rubber	A	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
NR-1-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
NR-1-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
NR-2-1	Natural rubber (3500-lb tensile strength)	B	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
NR-2-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
NR-2-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
SR-1-1	General service rubber	A	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
SR-1-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
SR-1-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
SR-2-1	General service rubber (2000-lb tensile strength)	B	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
SR-2-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
SR-2-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
SR-3-1	General service rubber (3000-lb tensile strength)	B	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
SR-3-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
SR-3-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
NEOR-1-1	Neoprene rubber	A	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
NEOR-1-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
NEOR-1-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
NEOR-2-1	Neoprene rubber	B	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
NEOR-2-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
NEOR-2-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
BUTYL-1-1	Butyl rubber	B	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
BUTYL-1-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
BUTYL-1-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
PVC-2-1	Type IV standard polyvinyl chloride	C	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-2-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
PVC-2-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
PVC-2A-1	Type IV arctic polyvinyl chloride	C	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-2A-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
PVC-2A-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
PVC-3-1	Type V standard polyvinyl chloride	C	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-3-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
PVC-3-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
PVC-3A-1	Type V arctic polyvinyl chloride	C	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-3A-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
PVC-3A-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
PVC-4-1	Polyvinyl chloride	A	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-4-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
PVC-4-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
PVC-5-1	Polyvinyl chloride	D	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound
PVC-5-2			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		
PVC-5-3			Sound	Sound	Sound	Sound	Sound	Sound	Sound	Sound	*		

\* Removed from exposure in June 1966 for tests.

\*\* The condition of all of these specimens was the same in 1967, 1968, 1969, and 1970.

(Sheet 2)

(Revised Jan 1972)

Table 4-WS

Section 30

## Record of Observations of Unstressed, Bent, and Embedded Specimens, Nonmetallic Waterstop Investigation

## Jackson Outdoor Exposure

1957- (Installed 1957)

Specimen No.	Description	Manu- facturer	Condition* of Unstressed Specimens, 1957-												
			1957	1958	1959	1960	1962	1963	1964	1965	1966	1967	1968	1969	1970
NR-1-1	Natural rubber	A	Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz
NR-1-2			Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	**	Crz	Crz	Crz	Crz
NR-1-3			Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	**				
NR-2-1	Natural rubber (3500-lb tensile strength)	B	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd
NR-2-2			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**				
NR-2-3			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**				
SR-1-1	General service rubber	A	Sd	Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz
SR-1-2			Sd	Sd	Sd	Sd	Crz	Crz	Crz	Crz	**				
SR-1-3			Sd	Sd	Sd	Sd	Crz	Crz	Crz	Crz	**				
SR-2-1	General service rubber (2000-lb tensile strength)	B	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd
SR-2-2			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**				
SR-2-3			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**				
SR-3-1	General service rubber (3000-lb tensile strength)	B	Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz
SR-3-2			Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	**				
SR-3-3			Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	**				
NEOR-1-1	Neoprene rubber	A	Sd	Sd	Sd	Sd	Crz	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd
NEOR-1-2			Sd	Sd	Sd	Sd	Crz	Sd	Sd	Sd	**				
NEOR-1-3			Sd	Sd	Sd	Sd	Crz	Sd	Sd	Sd	**				
NEOR-2-1	Neoprene rubber	B	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd
NEOR-2-2			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**				
NEOR-2-3			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**				
BUTYL-1-1	Butyl rubber	B	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd
BUTYL-1-2			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**				
BUTYL-1-3			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**				
PVC-2-1	Type IV standard polyvinyl chloride	C	Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz
PVC-2-2			Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	**				
PVC-2-3			Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	**				
PVC-2A-1	Type IV arctic polyvinyl chloride	C	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd
PVC-2A-2			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**				
PVC-2A-3			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**				
PVC-3-1	Type V standard polyvinyl chloride	C	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz
PVC-3-2			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**				
PVC-3-3			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**				
PVC-3A-1	Type V arctic polyvinyl chloride	C	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd
PVC-3A-2			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**				
PVC-3A-3			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**				
PVC-4-1	Polyvinyl chloride	A	Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz
PVC-4-2			Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	**				
PVC-4-3			Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	**				
PVC-5-1	Polyvinyl chloride	A	Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz
PVC-5-2			Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	**				
PVC-5-3			Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	**				

(Continued)

\* Conditions are described as sound (Sd), crazing (Crz).  
 \*\* Removed from exposure in June 1966 for tests.

(Sheet 1)

(Revised Jan 1972)

Table 4-WS (Continued)

Section 30

Specimen No.	Description	Manu- facturer	Condition* of Bent Specimens, 1957-1971													
			1957	1958	1959	1960	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
NR-1-1	Natural rubber	A	Sd	Crz	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd
NR-1-2			Sd	Crz	Cd	Cd	Cd	Cd	Cd	Cd	**					
NR-1-3			Sd	Crz	Cd	Cd	Cd	Cd	Cd	Cd	**					
NR-2-1	Natural rubber (3500-lb tensile strength)	B	Sd	Sd	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz
NR-2-2			Sd	Sd	Crz	Crz	Crz	Crz	Crz	Crz	**					
NR-2-3			Sd	Sd	Crz	Crz	Crz	Crz	Crz	Crz	**					
SR-1-1	General service rubber	A	Sd	Cd	B cd	B cd	B cd	B cd	B cd	B cd	B cd	B cd	B cd	B cd	B cd	B cd
SR-1-2			Sd	Cd	B cd	B cd	B cd	B cd	B cd	B cd	**					
SR-1-3			Sd	Cd	B cd	B cd	B cd	B cd	B cd	B cd	**					
SR-2-1	General service rubber (2000-lb tensile strength)	B	Sd	Sd	Crz	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd
SR-2-2			Sd	Crz	Crz	Cd	Cd	Cd	Cd	Cd	**					
SR-2-3			Sd	Sd	Crz	Cd	Cd	Cd	Cd	Cd	**					
SR-3-1	General service rubber (3000-lb tensile strength)	B	Sd	Cd	B cd	B cd	B cd	B cd	B cd	B cd	B cd	B cd	B cd	B cd	B cd	B cd
SR-3-2			Sd	Cd	B cd	B cd	B cd	B cd	B cd	B cd	**					
SR-3-3			Sd	Cd	B cd	B cd	B cd	B cd	B cd	B cd	**					
NEOR-1-1	Neoprene rubber	A	Sd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd
NEOR-1-2			Sd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	**					
NEOR-1-3			Sd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	**					
NEOR-2-1	Neoprene rubber	B	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd
NEOR-2-2			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**					
NEOR-2-3			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**					
BUTYL-1-1	Butyl rubber	B	Sd	Crz	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd
BUTYL-1-2			Sd	Crz	Cd	Cd	Cd	Cd	Cd	Cd	**					
BUTYL-1-3			Sd	Crz	Cd	Cd	Cd	Cd	Cd	Cd	**					
PVC-2-1	Type IV standard polyvinyl chloride	C	Sd	Sd	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz
PVC-2-2			Sd	Sd	Crz	Crz	Crz	Crz	Crz	Crz	**					
PVC-2-3			Sd	Sd	Crz	Crz	Crz	Crz	Crz	Crz	**					
PVC-2A-1	Type IV arctic polyvinyl chloride	C	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd
PVC-2A-2			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**					
PVC-2A-3			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**					
PVC-3-1	Type V standard polyvinyl chloride	C	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	Crz	Crz
PVC-3-2			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Crz	**					
PVC-3-3			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Crz	**					
PVC-3A-1	Type V arctic polyvinyl chloride	C	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Crz	Crz
PVC-3A-2			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**					
PVC-3A-3			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**					
PVC-4-1	Polyvinyl chloride	A	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	Crz	Crz
PVC-4-2			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Crz	**					
PVC-4-3			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Crz	**					
PVC-5-1	Polyvinyl chloride	A	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	Crz	Crz
PVC-5-2			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Crz	**					
PVC-5-3			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Crz	**					

(Continued)

\* Conditions are described as sound (Sd), crazing (Crz), cracked (Cd), and badly cracked (B cd).  
 \*\* Removed from exposure in June 1966 for tests.

(Sheet 2)

(Revised Jan 1972)

Table 4-WS (Concluded)

Section 30

Specimen No.	Description	Manu- facturer	Condition* of Embedded Specimens, 1957-1971													
			1957	1958	1959	1960	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
NR-1-37	Natural rubber	A	Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz
NR-1-38			Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	**					
NR-1-39			Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	**					
NR-2-112	Natural rubber (3500-lb tensile strength)	B	Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz
NR-2-113			Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	**					
NR-2-114			Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	**					
SR-1-43	General service rubber	A	Sd	Cd	B cd	B cd	B cd	B cd	B cd	C tn	**					
SR-1-44			Sd	Cd	B cd	B cd	B cd	B cd	B cd	C tn	**					
SR-1-45			Sd	Cd	B cd	B cd	B cd	B cd	B cd	C tn	**					
SR-2-115	General service rubber (2000-lb tensile strength)	B	Sd	Tn	C tn											
SR-2-116			Sd	Tn	C tn											
SR-2-117			Sd	Tn	C tn											
SR-3-118	General service rubber (3000-lb tensile strength)	B	Sd	Cd	B cd	B cd	B cd	Tn	Tn	C tn	**					
SR-3-119			Sd	Cd	B cd	B cd	B cd	Tn	Tn	C tn	**					
SR-3-120			Sd	Cd	B cd	B cd	B cd	Tn	Tn	C tn	**					
NEOR-1-40	Neoprene rubber	A	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd
NEOR-1-41			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**					
NEOR-1-42			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**					
NEOR-2-109	Neoprene rubber	B	Sd	Sd	Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz
NEOR-2-110			Sd	Sd	Sd	Sd	Sd	Crz	Crz	Crz	**					
NEOR-2-111			Sd	Sd	Sd	Sd	Sd	Crz	Crz	Crz	**					
BUTYL-1-106	Butyl rubber	B	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd
BUTYL-1-107			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**					
BUTYL-1-108			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**					
PVC-2-28	Type IV standard polyvinyl chloride	C	Sd	Sd	Sd	Sd	Sd	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz	Crz
PVC-2-29			Sd	Sd	Sd	Sd	Sd	Crz	Crz	Crz	**					
PVC-2-30			Sd	Sd	Sd	Sd	Sd	Crz	Crz	Crz	**					
PVC-2A-49	Type IV arctic polyvinyl chloride	C	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Crz	Crz
PVC-2A-50			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**					
PVC-2A-51			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**					
PVC-3-31	Type V standard polyvinyl chloride	C	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Crz	Crz
PVC-3-32			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**					
PVC-3-33			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**					
PVC-3A-52	Type V arctic polyvinyl chloride	C	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd
PVC-3A-53			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**					
PVC-3A-54			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**					
PVC-4-34	Polyvinyl chloride	A	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Crz	Crz
PVC-4-35			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**					
PVC-4-36			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**					
PVC-5-46	Polyvinyl chloride	D	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	Crz	Crz
PVC-5-47			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**					
PVC-5-48			Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd	**					

\* Conditions are described as sound (Sd), cracked (Cd), torn (Tn), badly cracked (B cd), completely torn (C tn), and crazing (Crz).

\*\* Removed from exposure in June 1966 for tests.

(Sheet 3)

Woven Plastic Test Program

The purpose of this investigation is to evaluate the durability of two types of woven plastic filter material under three exposure conditions.

The test specimens are 13-in.-square pieces of woven plastic and are exposed at two locations: Treat Island, Maine, and Jackson, Mississippi (indoors).

1963 Treat Island installation

In November 1963, 160 woven plastic pieces were installed at the Treat Island exposure station. Eighty pieces were installed in thin redwood frames (two pieces per frame) with a nominal 1-in. space between them for circulation of air. The redwood frames were contained in one long redwood box, slatted to permit circulation of air and seawater; the top of the box had an overhang, and baffles were provided to shade the plastic pieces from the sun at all times. The remaining 80 pieces were installed flat in two redwood boxes with a 2-in. layer of pea gravel top and bottom.

1963 Jackson installation

In November 1963, 80 woven plastic pieces were installed indoors at the WES Jackson installation. These specimens were installed in thin redwood frames contained in a long redwood box as were one set of the companion specimens at Treat Island.

Loss of test specimens

In July 1966, 60 specimens in redwood frames were lost overboard (two plastic pieces per frame). At that time, 20 of the frame specimens had already been returned to the laboratory for testing.

1967 Treat Island installation

In April 1967, 80 woven plastic pieces were installed at the Treat Island exposure station. All of these were installed in thin redwood frames (two pieces per frame) with a nominal 1-in. space between them for circulation of air. As in the 1963 installation, the redwood frames were contained in one long redwood box, slatted to permit circulation of air

and seawater. Baffles were provided to shade the plastic pieces from the sun at all times. This installation replaced the specimens lost overboard in July 1966.

Schedule of testing (from May 1967)

Every 6 months until November 1969, 12 specimens were removed from their exposure (four from Jackson, eight from Treat Island) and tested in the laboratory (see table 1-WPF).

In January 1970, this phase of the investigation was terminated. At that time only 64 specimens remained under test: 32 were in the pea gravel boxes at Treat Island and 32 were in frames (indoors) at the laboratory.

1970 installation

In March 1970, 22 plastic pieces were installed at Treat Island in redwood frames. This installation represented four additional types of plastic, three of which were woven plastics (see table 1-WPF). The schedule for laboratory testing of these samples has not yet been established.

Table 1-WPF

Woven Plastic Test Program Summary

<u>No. of Specimens</u>	<u>Exposure Conditions</u>	<u>Woven Plastic</u>	<u>No. of Specimens to be Removed from Exposure and Tested Every 6 months</u>
<u>Exposed at Treat Island, Maine (Installed November 1963)</u>			
40*	Wooden frames, vertical	Type F	0
40*	Wooden frames, vertical	Type P	0
40	Horizontal, pea gravel, Box F	Type F	2
40	Horizontal, pea gravel, Box P	Type P	2
<u>Exposed at Jackson, Miss. (Indoors) (Installed November 1963)</u>			
40	Wooden frames, vertical	Type F	2
40	Wooden frames, vertical	Type P	2
<u>Exposed at Treat Island, Maine (Installed April 1967)</u>			
40†	Wooden frames, vertical	Type F	2**
40†	Wooden frames, vertical	Type P	2**
<u>Exposed at Treat Island, Maine (Installed March 1970)</u>			
1	Wooden frames, vertical	Type F	
1	Wooden frames, vertical	Type P	
10	Wooden frames, vertical	Type L	
4	Wooden frames, vertical	Type PM (not a woven plastic)	
2	Wooden frames, vertical	Type PGB	
4	Wooden frames, vertical	Type Z	

\* Thirty of these specimens were lost overboard in July 1966. Ten of these specimens had been sent back to the laboratory for testing prior to July 1966.

\*\* Return of these specimens began in May 1967. No frame specimens were returned from Treat Island in November 1966.

† Thirty of these specimens were lost overboard in a storm in November 1969. Ten specimens have been tested in the laboratory after exposure.

(Revised Jan 1972)

Section 32

National Bureau of Standards Supersulfate Cement Program

In November 1957, 27 concrete beams (3 by 4 by 16 in.) were installed on the exposure rack at St. Augustine as part of a program being conducted by the National Bureau of Standards to investigate the properties of concrete containing supersulfate cements.

The 27 beams represented nine cements (3 beams per cement); other concrete characteristics were: slump,  $5 \pm 1$  in.; nominal cement factor, 5.5 bags per cu yd; aggregates, natural sand and natural gravel of 1-in. maximum size.

Table 1-SS lists these specimens and gives their exposure record, along with their cements.

Data collection on these specimens was discontinued after the 1970 inspection.

(Revised Sept 1966)

Table 1-SS

Section 32

Record of Testing of Concrete Beams, Supersulfate

Cement Program

1957- (Installed November 1957)

Beam No.	Cementitious Material		1957-1964 Readings				
	Type	Serial No.	1957 %E	1958 %E	1960 %E	1962 %E	1964 %E
1SS1	Supersulfate cement	1	100	113	103	99	102
1SS2			100	115	104	102	104
1SS3			100	114	100	99	102
2SS1	Supersulfate cement	2	100	109	109	103	105
2SS2			100	110	112	107	106
2SS3			100	109	110	105	109
3SS1	Supersulfate cement	3	100	119	113	106	107
3SS2			100	119	111	104	105
3SS3			100	121	111	105	106
4SS1	Supersulfate cement	4	100	116	102	99	101
4SS2			100	118	110	106	109
4SS3			100	117	110	106	108
5SS1	Supersulfate cement	5	100	109	109	100	105
5SS2			100	109	110	104	106
5SS3			100	109	109	105	106
6SS1	Portland, blast-furnace slag	6	100	113	109	94	84
6SS2			100	113	109	93	Failed
6SS3			100	112	107	96	95
7SS1	Type V	7	100	113	102	97	100
7SS2			100	112	101	99	99
7SS3			100	111	102	99	101
8SS1	Portland-pozzolan blend	8	100	112	110	99	105
8SS2			100	113	106	102	107
8SS3			100	112	108	*	
9SS1	High-alumina cement	9	100	112	105	101	108
9SS2			100	112	102	101	107
9SS3			100	114	105	105	110

(Continued)

\* Broken in handling.

(Sheet 1)

(Revised Sept 1970)

Table 1-SS (Concluded)

Section 32

Beam No.	Cementitious Material		1966-1968		Readings
	Type	Serial No.	1966 %E	1968 %E	1970 %E
1SS1	Supersulfate cement	1	101	97	96
1SS2			103	104	102
1SS3			100	104	102
2SS1	Supersulfate cement	2	105	104	104
2SS2			107	101	100
2SS3			108	109	108
3SS1	Supersulfate cement	3	107	105	105
3SS2			104	106	106
3SS3			106	101	101
4SS1	Supersulfate cement	4	100	105	104
4SS2			109	112	110
4SS3			107	114	112
5SS1	Supersulfate cement	5	104	105	104
5SS2			108	107	107
5SS3			106	111	Failed
6SS1	Portland, blast-furnace slag	6	Failed		
6SS3			94	86	85
7SS1	Type V	7	100	99	98
7SS2			99	101	99
7SS3			100	102	101
8SS1	Portland-pozzolan blend	8	111	109	108
8SS2			*		
8SS3					
9SS1	High-alumina cement	9	109	114	Lost
9SS2			107	104	Lost
9SS3			111	104	Lost

\* Broken in handling.

(Sheet 2)

Membrane Curing Program

On 12 June 1946, 14 box specimens were installed on top of the wharf at Treat Island, Maine. Exposure of these specimens is a phase of the investigation of the effect of method of curing on the durability of vertical concrete surfaces. Each of the specimens is a hollow, monolithic, concrete box with exterior vertical surfaces 24 in. wide and 20 in. high and with hollow, tapered, prismoidal centers 18 in. square at the top and 14 in. square at the bottom.

The specimens were made during the winter of 1942-43 and were formed out-of-doors, on the ground, at the moderate weathering exposure installation at Mount Vernon, N. Y. Each pair of adjacent exterior vertical surfaces represented a given test condition and the edge between each pair of similar surfaces was oriented in an east or west direction. The hollow centers were filled with earth.

After two and one-half winters of moderate weathering exposure (approximately 250 cycles of freezing-and-thawing), the specimens were emptied of earth and transferred to Treat Island, installed on top of the wharf with the same orientation as previously employed, and the centers were re-filled with earth.

Table 1-MCP lists these specimens and gives their present condition along with other pertinent information.

(Revised August 1977)

Table 1-MCP

Section 34'

## Record of Testing of Box Specimens, Membrane Curing Program

1959- (Installed June 1946)

Box No.	East Corner	West Corner	Admixture		Cement	Curing Material		Form Lining	Condition of Specimens, 1959-1961					
									13 Winters 1959		14 Winters 1960		15 Winters 1961	
			East	West		East	West		East	West	East	West	East	West
1	GVRW	GW	Resin	None	A	Water	Water	T-and-G*	Excel**	Excel	Excel	Excel	Excel	Excel
2	GVRCCW	GVRAHW	Resin + CC	Resin + AH	A	Water	Water	T-and-G	Excel	Excel	Excel	Excel	Excel	Excel
3	GCCJW	GCCW	Resin soap + CC	CC	A	Water	Water	T-and-G	Excel	Excel	Excel	Excel	Excel	Excel
4		GJW	Resin soap	Resin soap	A	Water	Water	T-and-G	Excel	Excel	Excel	Excel	Excel	Excel
5		AC	None	None	B	Air	Air	T-and-G	Excel	Excel	Excel	Excel	Excel	Excel
6	CAC	CWC	None	None	B	Air	Water	Lining A	Excel	Excel	Excel	Excel	Excel	Excel
7	RAC	RWC	None	None	B	Air	Water	Lining B	Excel	Excel	Excel	Excel	Excel	Excel
8		AHAC	AH	AH	B	Air	Air	T-and-G	Excel	Excel	Excel	Excel	Excel	Excel
9	B-3	B-1	None	None	B	HPB	RG	T-and-G	Excel	Excel	Excel	Excel	Excel	Excel
10	B-8	B-2	None	None	B	KC70	HPC	T-and-G	Excel	Excel	Excel	Excel	Excel	Excel
11	B-25	B-23	None	None	B	SP45W	CS45	T-and-G	Excel	Excel	Excel	Excel	Excel	Excel
12	B-24	B-29	None	None	B	SP45	DSA	T-and-G	Excel	Excel	Excel	Excel	Excel	Excel
13	B-17	B-28	None	None	B	AFMST	PENC	T-and-G	Excel	Excel	Excel	Excel	Excel	Excel
14	B-18	B-30	None	None	B	AIC	TFX199	T-and-G	Excel	Excel	Excel	Excel	Excel	Excel

	Condition of Specimens, 1962-1972															
	16 Winters 1962		17 Winters 1963		18 Winters 1964		19 Winters 1965		20 Winters 1966		24 Winters 1970++		25 Winters 1971		26 Winters 1972	
	East	West	East	West	East	West	East	West	East	West	East	West	East	West	East	West
1	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
2	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
3	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
4	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
5	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
6	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
7	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
8	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
9	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
10	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
11	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
12	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
13	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
14	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel

	Condition of Specimens, 1973-									
	27 Winters 1973		28 Winters 1974		29 Winters 1975		30 Winters 1976		31 Winters 1977	
	East	West	East	West	East	West	East	West	East	West
1	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
2	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
3	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
4	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
5	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
6	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
7	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
8	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
9	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
10	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
11	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
12	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
13	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel
14	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel	Excel

\* Tongue-and-groove lumber.

\*\* Excel denotes excellent.

† Sl ck denotes slight crack.

++ Condition of the specimens did not change from 1967 to 1971.

Quality Aggregate Investigation

The purpose of this investigation is to develop satisfactory test methods for evaluating the quality of aggregate larger than the 1-1/2-in. size.

During the period 1959-1962, 16 mass concrete cubes (8 cu ft) were fabricated for field exposure tests from 16 different concrete mixtures (one cube per mixture). All cubes were made of air-entrained concrete using type II portland cement, a 6-in. maximum size coarse aggregate, and a manufactured limestone sand as the fine aggregate. The test variables were water-cement ratio and kind of coarse aggregate; eight coarse aggregates and two water-cement ratios were used. Each cube was allowed to reach a minimum age of 1 year before installation at Treat Island.

1962 Installation

In November 1962, ten of these concrete cubes were installed at half-tide elevation on the beach at Treat Island for field exposure tests. Table 1-QA lists these specimens and gives their exposure record along with pertinent mixture data.

1963 Installation

In December 1963, the remaining six of these concrete cubes were installed at half-tide elevation on the beach at Treat Island. Table 2-QA lists these specimens and gives their exposure record.

(Revised August 1977)

Table 1-QA

Section 35

Record of Testing of Cubes Made for Quality Aggregate Investigation1962 Installation (Installed November 1962)

Cube No.	Date Made	Coarse Aggregate	Water-Cement Ratio (by Wt.)	Air Content* %	Slump* in.	1962-1968 Readings							
						Beach Row 2 (W to E)							
						0 Cycles 1962	106 Cycles 1963	241 Cycles 1964	404 Cycles 1965	534 Cycles 1966	690 Cycles 1967	875 Cycles 1968	
						Pulse Veloc fps	$\%V^2$	$\%V^2$	$\%V^2$	$\%V^2$	$\%V^2$	$\%V^2$	
Q-1	Mar 1959	Limestone C	0.5	5.3	1	17,315	100	104	97	103	96	88	79
Q-2	July 1959	Limestone C	0.8	5.0	1-3/4	16,065	100	65	72	41	Failed		
Q-3	June 1959	Graywacke	0.5	5.5	1-3/4	13,515	100	108	112	126	112	110	NR**
Q-4	June 1959	Graywacke	0.8	5.4	2	12,780	100	99	102	91	46	66	Failed
Q-5	Oct 1959	Natural gravel A	0.5	5.2	1-1/2	15,150	100	97	100	106	97	100	100
Q-6	Oct 1959	Natural gravel A	0.8	5.3	2	14,035	100	97	89	75	51	Failed	
Q-7	Feb 1960	Limestone B	0.5	5.0	1-3/4	16,000	100	102	102	108	97	90	82
Q-8	Feb 1960	Limestone B	0.8	4.9	1-1/4	15,150	100	77	57	NR**	33†	Failed	
Q-9	Mar 1960	Limestone A	0.5	4.8	1-1/4	16,600	100	94	97	101	86	82	93
Q-10	Mar 1960	Limestone A	0.8	5.2	1-3/4	16,065	100	96	98	81	75	79	60

Cube No.	Date Made	Coarse Aggregate	Water-Cement Ratio (by Wt.)	Air Content* %	Slump* in.	1969-1977 Readings							
						1029 Cycles 1969	1182 Cycles 1970	1351 Cycles 1971	1508 Cycles 1972	1648 Cycles 1973	1784 Cycles 1974	1896 Cycles 1975	2042 Cycles 1976
						$\%V^2$	$\%V^2$	$\%V^2$	$\%V^2$	$\%V^2$	$\%V^2$	$\%V^2$	$\%V^2$
Q-1	Mar 1959	Limestone C	0.5	5.3	1	Failed							
Q-3	June 1959	Graywacke	0.5	5.5	1-3/4	NR**	NR**	Failed					
Q-5	Oct 1959	Natural gravel A	0.5	5.2	1-1/2	73	67	58	58	††	27	Failed	
Q-7	Feb 1960	Limestone B	0.5	5.0	1-3/4	56	54	29	43	††	17	41	Failed
Q-9	Mar 1960	Limestone A	0.5	4.8	1-1/4	66	64	53	65	††	58	56	Failed
Q-10	Mar 1960	Limestone A	0.8	5.2	1-3/4	42	NR**	Failed					

\* Air content and slump of that portion of the concrete containing aggregate smaller than 1-1/2 in. in size.

\*\* NR = no satisfactory reading was obtained due to condition of specimen; however, specimen cannot as yet be adjudged as "failed."

† This reading is doubtful because of deteriorated condition of specimen.

†† Equipment malfunctioned in 1973.

(Revised August 1977)

Table 2-QA

Section 35

Record of Testing of Cubes Made for Quality Aggregate Investigation1963 Installation (Installed December 1963)

Cube No.	Date Made	Coarse Aggregate	Water-Cement Ratio (by Wt)	Air Content* %	Slump* in.	Beach Row A-1 (W to E)							
						1963-1969 Readings							
						0 Cycles 1963 Pulse Veloc fps	121 Cycles 1964 %V <sup>2</sup>	284 Cycles 1965 %V <sup>2</sup>	414 Cycles 1966 %V <sup>2</sup>	570 Cycles 1967 %V <sup>2</sup>	755 Cycles 1968 %V <sup>2</sup>	909 Cycles 1969 %V <sup>2</sup>	
Q-11	Aug 1962	Dolomite	0.5	4.8	1-1/2	15,565	100	102	119	117	88	89	73
Q-12	Aug 1962	Dolomite	0.8	4.9	1-1/2	14,870	100	112	110	122	51	Failed	
Q-13	July 1962	Natural gravel B	0.5	5.0	1-1/2	15,875	100	114	122	112	107	105	91
Q-14	Aug 1962	Natural gravel B	0.8	4.9	1-1/2	15,505	100	103	118	118	102	84	66
Q-15	Aug 1962	Gneiss	0.5	4.8	1-1/2	14,335	100	124	140	135	131	121	107
Q-16	Aug 1962	Gneiss	0.8	4.8	1-1/2	13,890	100	122	112	139	76	Failed	

Cube No.	Date Made	Coarse Aggregate	Water-Cement Ratio (by Wt)	Air Content* %	Slump* in.	1970-1976 Readings						
						1062 Cycles 1970 %V <sup>2</sup>	1231 Cycles 1971 %V <sup>2</sup>	1388 Cycles 1972 %V <sup>2</sup>	1528 Cycles 1973 %V <sup>2</sup>	1664 Cycles 1974 %V <sup>2</sup>	1776 Cycles 1975 %V <sup>2</sup>	1922 Cycles 1976 %V <sup>2</sup>
Q-11	Aug 1962	Dolomite	0.5	4.8	1-1/2	Failed						
Q-13	July 1962	Natural gravel B	0.5	5.0	1-1/2	81	80	90	++	118	105	94
Q-14	Aug 1962	Natural gravel B	0.8	4.9	1-1/2	†	Failed					
Q-15	Aug 1962	Gneiss	0.5	4.8	1-1/2	99	104	115	++	120	123	116

Cube No.	Date Made	Coarse Aggregate	Water-Cement Ratio (by Wt)	Air Content* %	Slump* in.	1977- Readings	
						1999 Cycles 1977 %V <sup>2</sup>	
Q-11	Aug 1962	Dolomite	0.5	4.8	1-1/2		
Q-13	July 1962	Natural gravel B	0.5	5.0	1-1/2	94	
Q-14	Aug 1962	Natural gravel B	0.8	4.9	1-1/2		
Q-15	Aug 1962	Gneiss	0.5	4.8	1-1/2	109	

\* Air content and slump of that portion of the concrete containing aggregate smaller than 1-1/2 in. in size.

† A satisfactory reading could not be taken because of the condition of the specimen.

++ Equipment malfunctioned in 1973.

Cement-Replacement Materials Investigation, Phase G\*

In November 1962, two concrete prisms (18 by 18 by 36 in.) were installed at half-tide elevation on the beach at Treat Island as a part of Phase G (field phase) of the cement-replacement materials investigation.\* Phase G (field phase) involved the proportioning, outdoor mixing, and placing of lean mass concrete containing pozzolans. The purpose of this installation is to develop information about the durability of these lean mass concretes.

The prisms were made from two different concrete mixtures (one prism per mixture); the coarse and fine aggregates used in both mixtures were crushed limestone. Each concrete mixture was air-entrained and each contained type II portland cement and one replacement material. The mixture data are tabulated below. Table 1-CRMI-PG lists these concrete prisms and gives their exposure record.

Speci- men and Mix No.	Date Cast 1962	Portland Cement %, by Wt	Replacement Material		Max Size Coarse Aggr	Nominal Cemen- titious Material Factor bags/ cu yd	Water- cement Ratio by Wt	Nominal Slump in.	Air** %
			Type	% by Wt Used					
1	9-12	48.5	Fly ash	51.5	6	2.1	0.62	1-3/4	5.0- 6.6
6	6-21	57.3	Shale	42.7	6	1.7	0.85	1-3/4	5.0- 6.0

\*\* Air content of that portion of the concrete containing aggregate smaller than 1-1/2-in. size.

\* See: (1) U. S. Army Engineer Waterways Experiment Station, CE, Investigation of Cement-Replacement Materials; Use of Large Amounts of Pozzolans in Lean Mass Concrete, by W. O. Tynes, Miscellaneous Paper No. 6-123, Report 10 (Vicksburg, Miss., August 1962).

(2) U. S. Army Engineer Waterways Experiment Station, CE, Investigation of Cement-Replacement Materials; Use of Large Amounts of of Pozzolans in Lean Mass Concrete (Second Phase), by W. O. Tynes, Miscellaneous Paper No. 6-123, Report 14 (Vicksburg, Miss., October 1966).

(Revised Jan 1972)

Table 1-CRMI-PG

Section 36

Record of Testing of Prisms Made for Cement-  
Replacement Materials Investigation  
Phase G, 1962- (Installed November 1962)

				Beach Row 2 (E to W)			
Specimen and Mix No.	Portland Cement %	Replace- ment Material* %	Maximum Aggregate Size in.	1962-1964 Readings			
				0 Cycles 1962	106	241	
				Pulse Veloc	Cycles 1963	Cycles 1964	
				fps	%V <sup>2</sup>	%V <sup>2</sup>	%V <sup>2</sup>
1	48.5**	51.5**	6	16,665	100	102	95
6	57.3**	42.7**	6	15,305	100	94	92
				1965-1968 Readings			
				404	534	690	875
				Cycles	Cycles	Cycles	Cycles
				1965	1966	1967	1968
				%V <sup>2</sup>	%V <sup>2</sup>	%V <sup>2</sup>	%V <sup>2</sup>
1	48.5**	51.5**	6	94	76	79	66
6	57.3**	42.7**	6	119	85	†	†
				1969- Readings			
				1029	1182	1351	
				Cycles	Cycles	Cycles	
				1969	1970	1971	
				%V <sup>2</sup>	%V <sup>2</sup>	%V <sup>2</sup>	
1	48.5**	51.5**	6	†	†	Failed	
6	57.3**	42.7**	6	†	Failed		

\* Replacement material in mix 1 was fly ash; replacement material in mix 6 was shale.

\*\* Percent by weight of total cementitious material (cement plus pozzolan).

† Faces of prism too rough to obtain satisfactory reading.

Maximum Size of Coarse Aggregate Program

In December 1963, 18 mass concrete prisms (18 by 18 by 36 in.) were installed at half-tide elevation on the beach at Treat Island.

The objective of this program was to determine if the maximum size of coarse aggregate used in mass concrete could be reduced from 6 to 3 in. without loss in quality of concrete.

The prisms were made from 18 different concrete mixtures (one prism per mixture); the coarse and fine aggregate used in all mixtures was a crushed limestone. Each concrete mixture was air-entrained ( $5 \pm 1$  percent) with a slump of  $2 \pm 1/2$  in., and each contained type II portland cement. Cement factors varied from 2 to 3 bags per cu yd; 12 mixtures contained a cement-replacement material. The maximum size of aggregate in all mixtures was either 3 or 6 in.

Table 1-CAP lists these concrete prisms and gives their exposure record along with other pertinent information.

(Revised Sept 1966)

Table 1-CAP

Section 37

Record of Testing of Prisms Made for Maximum Size  
of Coarse Aggregate Program  
1963- (Installed December 1963)

Speci- men and Mix No.	Date Made	Nominal Cement Factor bags/ cu yd	Replace- ment Material*	Actual Sand: Aggre- gate Ratio %	Max Size Coarse Aggre- gate in.	Beach Row 2 (W to E)			
						0 Cycles 1963		121 Cycles 1964	284 Cycles 1965
						Pulse Velocity fps	%V <sup>2</sup>		
1	Sept 1963	2.0	None	30	3	14,285	100	129	121
2	Sept 1963	2.0	None	24	6	15,545	100	109	114
3	Sept 1963	2.0	Fly ash	30	3	14,150	100	93	**
4	Sept 1963	2.0	Fly ash	24	6	15,385	100	115	115
5	Sept 1963	2.0	Shale	30	3	14,780	100	107	119
6	Sept 1963	2.0	Shale	24	6	16,395	100	107	109
7	Sept 1963	2.5	None	30	3	14,850	100	117	119
8	Sept 1963	2.5	None	23	6	16,215	100	110	113
9	Sept 1963	2.5	Fly ash	30	3	15,465	100	104	115
10	Sept 1963	2.5	Fly ash	23	6	16,130	100	107	114
11	Oct 1963	2.5	Shale	30	3	15,305	100	104	116
12	Oct 1963	2.5	Shale	23	6	15,955	100	106	113
13	Oct 1963	3.0	None	29	3	14,925	100	113	126
14	Oct 1963	3.0	None	22	6	16,130	100	104	113
15	Oct 1963	3.0	Fly ash	29	3	14,705	100	113	136
16	Oct 1963	3.0	Fly ash	22	6	15,875	100	107	109
17	Oct 1963	3.0	Shale	29	3	15,385	100	111	123
18	Oct 1963	3.0	Shale	22	6	15,955	100	108	118

(Continued)

Note: The following specimens were made on the same day: 1 and 2, 3 and 4, 5 and 6, 7 and 8, 9 and 10, 11 and 12, 13 and 14, 15 and 16, 17 and 18; in other words, the specimens were made on 9 different days (2 per day).

\* 30% replacement by solid volume.

\*\* Condition of this prism precluded pulse velocity testing.

(Sheet 1)

(Revised Sept 1970)

Table 1-CAP (Continued)

Section 37

Specimen and Mix No.	Date Made	Nominal Cement Factor bags/ cu yd	Replace- ment Material	Actual Sand: Aggre- gate Ratio %	Max Size Coarse Aggre- gate in.	Beach Row 2 (W to E)			
						414 Cycles 1966	570 Cycles 1967	755 Cycles 1968	909 Cycles 1969
						%V <sup>2</sup>	%V <sup>2</sup>	%V <sup>2</sup>	%V <sup>2</sup>
1	Sept 1963	2.0	None	30	3	106	†	Failed	
2	Sept 1963	2.0	None	24	6	103	88	102	†
3	Sept 1963	2.0	Fly ash	30	3	Failed			
4	Sept 1963	2.0	Fly ash	24	6	108	104	103	97
5	Sept 1963	2.0	Shale	30	3	108	107	100	†
6	Sept 1963	2.0	Shale	24	6	97	94	92	88
7	Sept 1963	2.5	None	30	3	111	113	110	106
8	Sept 1963	2.5	None	23	6	106	103	106	91
9	Sept 1963	2.5	Fly ash	30	3	100	91	93	85
10	Sept 1963	2.5	Fly ash	23	6	101	94	95	85
11	Oct 1963	2.5	Shale	30	3	108	99	101	95
12	Oct 1963	2.5	Shale	23	6	101	101	100	88
13	Oct 1963	3.0	None	29	3	112	117	112	103
14	Oct 1963	3.0	None	22	6	100	100	99	92
15	Oct 1963	3.0	Fly ash	29	3	115	114	114	110
16	Oct 1963	3.0	Fly ash	22	6	108	100	103	96
17	Oct 1963	3.0	Shale	29	3	111	110	106	97
18	Oct 1963	3.0	Shale	22	6	108	101	103	94

† End of prism too rough to obtain satisfactory reading.

(Revised August 1977)

Table 1-CAP (Continued)

Section 37

Specimen and Mix No.	Date Made	Nominal Cement Factor bags/ cu yd	Replace- ment Material	Actual Sand: Aggre- gate Ratio %	Max Size Coarse Aggre- gate in.	Beach Row 2 (W to E)					
						1970-1975 Readings					
						1062 Cycles 1970	1231 Cycles 1971	1388 Cycles 1972	1528 Cycles 1973	1664 Cycles 1974	1776 Cycles 1975
						$\%V^2$	$\%V^2$	$\%V^2$	$\%V^2$	$\%V^2$	$\%V^2$
2	Sept 1963	2.0	None	24	6	†	Failed				
4	Sept 1963	2.0	Fly ash	24	6	86	†	Failed			
5	Sept 1963	2.0	Shale	30	3	†	Failed				
6	Sept 1963	2.0	Shale	24	6	84	†	Failed			
7	Sept 1963	2.5	None	30	3	104	76	104	++	84	106
8	Sept 1963	2.5	None	23	6	87	NR	86	++	104	94
9	Sept 1963	2.5	Fly ash	30	3	Failed					
10	Sept 1963	2.5	Fly ash	23	6	80	NR	86	++	38	Failed
11	Oct 1963	2.5	Shale	30	3	88	NR	88	++	Failed	
12	Oct 1963	2.5	Shale	23	6	83	20	84	++	96	92
13	Oct 1963	3.0	None	29	3	100	NR	100	++	116	113
14	Oct 1963	3.0	None	22	6	89	34	91	++	84	71
15	Oct 1963	3.0	Fly ash	29	3	91	90	109	++	122	118
16	Oct 1963	3.0	Fly ash	22	6	89	74	94	++	107	106
17	Oct 1963	3.0	Shale	29	3	95	72	99	++	112	114
18	Oct 1963	3.0	Shale	22	6	91	80	102	++	108	108
						1976- Readings					
						1922 Cycles 1976	1999 Cycles 1977				
						$\%V^2$	$\%V^2$				
2	Sept 1963	2.0	None	24	6						
4	Sept 1963	2.0	Fly ash	24	6						
5	Sept 1963	2.0	Shale	30	3						
6	Sept 1963	2.0	Shale	24	6						
7	Sept 1963	2.5	None	30	3	Failed					
8	Sept 1963	2.5	None	23	6	83	Failed				
9	Sept 1963	2.5	Fly ash	30	3						
10	Sept 1963	2.5	Fly ash	23	6						
11	Oct 1963	2.5	Shale	30	3						
12	Oct 1963	2.5	Shale	23	6	67	Failed				
13	Oct 1963	3.0	None	29	3	101	95				
14	Oct 1963	3.0	None	22	6	71	81				
15	Oct 1963	3.0	Fly ash	29	3	115	103				
16	Oct 1963	3.0	Fly ash	22	6	89	65				
17	Oct 1963	3.0	Shale	29	3	86	47				
18	Oct 1963	3.0	Shale	22	6	77	59				

† End of prism too rough to obtain satisfactory reading.

++ Equipment malfunctioned in 1973.

NR Unable to obtain satisfactory reading, although an attempt was made to do so.

(Sheet 3)

Maximum Allowable Water-cement Ratio Investigation

In December 1964, 24 concrete prisms (18 by 18 by 36 in.) were installed on the beach at Treat Island. The objective of this installation was to observe the durability of mass concrete mixtures in which the water-cement ratios varied from 0.6 to 1.1 by weight.

The prisms were made from 12 concrete mixtures (two prisms per mixture); the coarse and fine aggregate used in all mixtures was a crushed limestone. The maximum size of the aggregate was 6 in. Each concrete mixture was air-entrained ( $5 \pm 1\%$ ) with a slump of  $2 \pm 1/2$  in., and each contained type II portland cement. Cement factors varied from 1.59 to 2.93 bags per cu yd; 6 mixtures contained a cement-replacement material (30% by solid volume).

Table 1-MAWC lists these concrete prisms and gives their exposure record along with other pertinent information.

(Revised Sept 1968)

Table 1-MAWC

Section 38

Record of Testing of Prisms Made for Maximum  
Allowable Water-Cement Ratio Investigation  
 1964- (Installed December 1964)

Prism No.	Date Made	Type Cement	Replacement Material*	Water-Cement Ratio		Cement Factor bags/cu yd	0 Cycles 1964		Beach, Row A-1 152 Cycles 1965
				gals/bag	by weight		Pulse Velocity fps	$\Delta V^2$	$\Delta V^2$
Mix 1, Rd 1	Feb 1964	II	None	6.8	0.6	2.93	16,395	100	106
Rd 2	Aug 1964	II	None	6.8	0.6	2.93	16,130	100	114
Mix 2, Rd 1	May 1964	II	None	7.9	0.7	2.51	16,215	100	116
Rd 2	July 1964	II	None	7.9	0.7	2.51	16,665	100	108
Mix 3, Rd 1	June 1964	II	None	9.0	0.8	2.20	16,485	100	109
Rd 2	July 1964	II	None	9.0	0.8	2.20	16,395	100	111
Mix 4, Rd 1	June 1964	II	None	10.2	0.9	1.95	16,215	100	108
Rd 2	Aug 1964	II	None	10.2	0.9	1.95	16,045	100	107
Mix 5, Rd 1	Apr 1964	II	None	11.3	1.0	1.76	15,705	100	100
Rd 2	Aug 1964	II	None	11.3	1.0	1.76	15,875	100	104
Mix 6, Rd 1	Apr 1964	II	None	12.4	1.1	1.59	15,230	100	106
Rd 2	Aug 1964	II	None	12.4	1.1	1.59	15,150	100	111
Mix 7, Rd 1	Mar 1964	II	Fly ash	6.4	0.6	2.93	17,240	100	95
Rd 2	Aug 1964	II	Fly ash	6.4	0.6	2.93	16,575	100	103
Mix 8, Rd 1	June 1964	II	Fly ash	7.4	0.7	2.51	16,305	100	113
Rd 2	June 1964	II	Fly ash	7.4	0.7	2.51	16,760	100	102
Mix 9, Rd 1	Mar 1964	II	Fly ash	8.4	0.8	2.20	16,215	100	106
Rd 2	Aug 1964	II	Fly ash	8.4	0.8	2.20	16,215	100	108
Mix 10, Rd 1	June 1964	II	Fly ash	9.6	0.9	1.95	16,215	100	106
Rd 2	Aug 1964	II	Fly ash	9.6	0.9	1.95	15,385	100	111
Mix 11, Rd 1	June 1964	II	Fly ash	10.6	1.0	1.76	16,395	100	101
Rd 2	Aug 1964	II	Fly ash	10.6	1.0	1.76	16,130	100	110
Mix 12, Rd 1	June 1964	II	Fly ash	11.6	1.1	1.59	15,955	100	102
Rd 2	Aug 1964	II	Fly ash	11.6	1.1	1.59	16,130	100	89

Prism No.	Date Made	Type Cement	Replacement Material*	Water-Cement Ratio		Cement Factor bags/cu yd	282 Cycles 1966	438 Cycles 1967
				gals/bag	by weight		$\Delta V^2$	$\Delta V^2$
Mix 1, Rd 1	Feb 1964	II	None	6.8	0.6	2.93	103	112
Rd 2	Aug 1964	II	None	6.8	0.6	2.93	107	117
Mix 2, Rd 1	May 1964	II	None	7.9	0.7	2.51	106	116
Rd 2	July 1964	II	None	7.9	0.7	2.51	100	113
Mix 3, Rd 1	June 1964	II	None	9.0	0.8	2.20	102	109
Rd 2	July 1964	II	None	9.0	0.8	2.20	103	111
Mix 4, Rd 1	June 1964	II	None	10.2	0.9	1.95	106	109
Rd 2	Aug 1964	II	None	10.2	0.9	1.95	107	116
Mix 5, Rd 1	Apr 1964	II	None	11.3	1.0	1.76	111	103
Rd 2	Aug 1964	II	None	11.3	1.0	1.76	110	108
Mix 6, Rd 1	Apr 1964	II	None	12.4	1.1	1.59	70	99
Rd 2	Aug 1964	II	None	12.4	1.1	1.59	93	82
Mix 7, Rd 1	Mar 1964	II	Fly ash	6.4	0.6	2.93	93	101
Rd 2	Aug 1964	II	Fly ash	6.4	0.6	2.93	101	113
Mix 8, Rd 1	June 1964	II	Fly ash	7.4	0.7	2.51	103	111
Rd 2	June 1964	II	Fly ash	7.4	0.7	2.51	99	110
Mix 9, Rd 1	Mar 1964	II	Fly ash	8.4	0.8	2.20	106	113
Rd 2	Aug 1964	II	Fly ash	8.4	0.8	2.20	104	117
Mix 10, Rd 1	June 1964	II	Fly ash	9.6	0.9	1.95	90	106
Rd 2	Aug 1964	II	Fly ash	9.6	0.9	1.95	105	115
Mix 11, Rd 1	June 1964	II	Fly ash	10.6	1.0	1.76	93	101
Rd 2	Aug 1964	II	Fly ash	10.6	1.0	1.76	106	114
Mix 12, Rd 1	June 1964	II	Fly ash	11.6	1.1	1.59	98	103
Rd 2	Aug 1964	II	Fly ash	11.6	1.1	1.59	96	99

(Continued)

\* 30% replacement by solid volume.

(Sheet 1)

(Revised August 1977)  
Table 1-MAWC (Continued)

Section 38

Prism No.	Date Made	Type Cement	Replacement Material*	Water-Cement Ratio		Cement Factor bags/cu yd	Beach Row A-1				
				gals/bag	by weight		623 Cycles 1968 g <sup>2</sup>	777 Cycles 1969 g <sup>2</sup>	930 Cycles 1970 g <sup>2</sup>	1099 Cycles 1971 g <sup>2</sup>	1256 Cycles 1972 g <sup>2</sup>
Mix 1, Rd 1	Feb 1964	II	None	6.8	0.6	2.93	111	115	109	102	88
Rd 2	Aug 1964	II	None	6.8	0.6	2.93	117	102	NR	106	91
Mix 2, Rd 1	May 1964	II	None	7.9	0.7	2.51	108	100	102	87	75
Rd 2	July 1964	II	None	7.9	0.7	2.51	108	101	121	115	66
Mix 3, Rd 1	June 1964	II	None	9.0	0.8	2.20	105	97	98	75	65
Rd 2	July 1964	II	None	9.0	0.8	2.20	110	99	88	82	78
Mix 4, Rd 1	June 1964	II	None	10.2	0.9	1.95	106	NR**	NR	NR	NR
Rd 2	Aug 1964	II	None	10.2	0.9	1.95	112	101	91	80	35
Mix 5, Rd 1	Apr 1964	II	None	11.3	1.0	1.76	100	77	NR	NR	Failed
Rd 2	Aug 1964	II	None	11.3	1.0	1.76	105	82	NR	NR	Failed
Mix 6, Rd 1	Apr 1964	II	None	12.4	1.1	1.59	57	+	Failed		
Rd 2	Aug 1964	II	None	12.4	1.1	1.59	78	NR	Failed		
Mix 7, Rd 1	Mar 1964	II	Fly ash	6.4	0.6	2.93	93	88	102	88	84
Rd 2	Aug 1964	II	Fly ash	6.4	0.6	2.93	109	101	97	99	93
Mix 8, Rd 1	June 1964	II	Fly ash	7.4	0.7	2.51	103	100	107	90	NR
Rd 2	June 1964	II	Fly ash	7.4	0.7	2.51	105	96	100	85	NR
Mix 9, Rd 1	Mar 1964	II	Fly ash	8.4	0.8	2.20	110	95	74	86	NR
Rd 2	Aug 1964	II	Fly ash	8.4	0.8	2.20	113	97	95	NR	NR
Mix 10, Rd 1	June 1964	II	Fly ash	9.6	0.9	1.95	110	NR	NR	NR	NR
Rd 2	Aug 1964	II	Fly ash	9.6	0.9	1.95	115	NR	NR	NR	NR
Mix 11, Rd 1	June 1964	II	Fly ash	10.6	1.0	1.76	102	61	NR	NR	NR
Rd 2	Aug 1964	II	Fly ash	10.6	1.0	1.76	110	98	97	90	NR
Mix 12, Rd 1	June 1964	II	Fly ash	11.6	1.1	1.59	106	87	76	NR	NR
Rd 2	Aug 1964	II	Fly ash	11.6	1.1	1.59	71	NR	NR	NR	NR

Prism No.	Date Made	Type Cement	Replacement Material*	Water-Cement Ratio		Cement Factor bags/cu yd	Cycles				
				gals/bag	by weight		1396 1973 g <sup>2</sup>	1532 1974 g <sup>2</sup>	1644 1975 g <sup>2</sup>	1790 1976 g <sup>2</sup>	1889 1977 g <sup>2</sup>
Mix 1, Rd 1	Feb 1964	II	None	6.8	0.6	2.93	++	109	103	69	96
Rd 2	Aug 1964	II	None	6.8	0.6	2.93	++	107	112	107	98
Mix 2, Rd 1	May 1964	II	None	7.9	0.7	2.51	++	94	109	86	77
Rd 2	July 1964	II	None	7.9	0.7	2.51	++	105	118	112	51
Mix 3, Rd 1	June 1964	II	None	9.0	0.8	2.20	++	Failed			
Rd 2	July 1964	II	None	9.0	0.8	2.20	++	89	102	Failed	
Mix 4, Rd 1	June 1964	II	None	10.2	0.9	1.95	++	Failed			
Rd 2	Aug 1964	II	None	10.2	0.9	1.95	++	88	84	Failed	
Mix 5, Rd 1	Apr 1964	II	None	11.3	1.0	1.76					
Rd 2	Aug 1964	II	None	11.3	1.0	1.76					
Mix 6, Rd 1	Apr 1964	II	None	12.4	1.1	1.59					
Rd 2	Aug 1964	II	None	12.4	1.1	1.59					
Mix 7, Rd 1	Mar 1964	II	Fly ash	6.4	0.6	2.93	++	93	NR	59	88
Rd 2	Aug 1964	II	Fly ash	6.4	0.6	2.93	++	99	102	96	38
Mix 8, Rd 1	June 1964	II	Fly ash	7.4	0.7	2.51	++	104	109	105	Failed
Rd 2	June 1964	II	Fly ash	7.4	0.7	2.51	++	99	114	Failed	
Mix 9, Rd 1	Mar 1964	II	Fly ash	8.4	0.8	2.20	++	103	108	Failed	
Rd 2	Aug 1964	II	Fly ash	8.4	0.8	2.20	++	Failed			
Mix 10, Rd 1	June 1964	II	Fly ash	9.6	0.9	1.95	++	Failed			
Rd 2	Aug 1964	II	Fly ash	9.6	0.9	1.95	++	Failed			
Mix 11, Rd 1	June 1964	II	Fly ash	10.6	1.0	1.76	++	Failed			
Rd 2	Aug 1964	II	Fly ash	10.6	1.0	1.76	++	103	93	Failed	
Mix 12, Rd 1	June 1964	II	Fly ash	11.6	1.1	1.59	++	Failed			
Rd 2	Aug 1964	II	Fly ash	11.6	1.1	1.59	++	Failed			

\* 30% replacement by solid volume.

\*\* NR denotes that a satisfactory reading was not obtained although an attempt was made.

+ A pulse velocity reading could not be taken through the path previously used because of the poor condition of the specimen.

++ Equipment malfunctioned in 1973.

(Sheet 2)

Curing Investigation

In June 1968, 56 mass concrete prisms (18- by 18- by 36-in.) were installed on the Treat Island exposure rack.

The purpose of this installation is to develop information about the durability of mass concrete mixtures that contain special cements or pozzolans.

The prisms were made from seven concrete mixtures (eight prisms per mixture); the coarse and fine aggregate used in all mixtures was a crushed limestone, maximum size 6-in. Each concrete mixture was air-entrained ( $5.5 \pm 1$  percent) with a slump of  $1-1/2 \pm 1/2$  in. and a cement factor of 2.5 bags per cu yd. One portland blast-furnace slag cement, two type II portland cements, one blend of type II portland cement and natural cement, and three blends of type II portland cement with a replacement material (fly ash or calcined shale) were used. Four curing conditions were utilized (14 prisms per curing condition):

<u>Curing Condition No.</u>	<u>Days of Fog Room Curing</u>	<u>Subsequent Curing</u>
1	14	Laboratory air
2	21	Laboratory air
3	2	Membrane curing compound
4	2	Laboratory air

Table 1-CT lists these concrete prisms and gives their exposure record along with other pertinent information.

(Revised Jan 1972)

Table 1-CT

Section 39

Record of Testing of Prisms Made for Curing Investigation  
1968- (Installed June 1968 at Treat Island, Me.)

Prism No.	Position on Rack*	Curing Condition**	Type II Portland Cement %†	Other Cement %	Other Replacement Material %	Exposure Rack, Row 1							
						0 Cycles, 1968		154 Cycles 1969		307 Cycles 1970		476 Cycles 1971	
						%E	Pulse Veloc fps	%E	%V	%E	%V	%E	%V
30021	10	1	100 (cement A)	None	None	100	16,305	100		104	106	102	105
30022	49					100	16,485	100		100	103	97	102
40021	14	2				100	16,575	100		103	103	99	99
40022	44					100	16,215	100		103	108	100	108
50021	8	3				100	16,045	100		108	114	95	114
50022	31					100	15,705	100		104	113	104	112
60021	23	4				100	15,955	100		110	106	108	100
60022	30					100	15,705	100		105	112	104	112
30421	40	1	100 (cement B)	None	None	100	17,145	100		99	105	100	106
30422	20					100	17,045	100		98	106	98	103
40421	15	2				100	17,045	100		98	106	95	105
40422	26					100	16,665	100		102	107	102	104
50421	28	3				100	16,215	100		103	112	99	108
50422	6					100	15,955	100		109	114	107	103
60421	35	4				100	16,395	100		99	113	98	109
60422	11					100	15,790	100		107	115	105	112
325S1	18	1	75 (cement A)	None	25 (calcined shale)	100	16,395	100		96	115	95	115
325S2	1					100	15,790	100		98	111	94	117
425S1	42	2				100	16,130	100		97	117	84	113
425S2	38					100	16,215	100		95	108	95	108
525S1	51	3			25 (shale)	100	15,705	100		99	131	96	127
525S2	12					100	15,465	100		100	116	99	113
625S1	27	4				100	16,130	100		102	112	100	109
625S2	13					100	15,875	100		100	119	99	116
335N1	3	1	65 (cement A)	35 (nat cement)	None	100	15,955	100		101	108	98	102
335N2	24					100	16,305	100		100	107	98	104
435N1	50	2				100	16,575	100		98	89	96	85
435N2	9					100	15,790	100		104	110	103	110
535N1	55	3				100	16,395	100		96	110	93	109
535N2	39					100	15,875	100		101	113	99	113
635N1	4	4				100	15,790	100		103	107	100	104
635N2	7					100	16,215	100		95	116	107	116
325F1	53	1	75 (cement A)	None	25 (fly ash)	100	17,750	100		83	108	79	107
325F2	45					100	16,130	100		94	109	91	110
425F1	56	2				100	16,855	100		96	104	93	103
425F2	25					100	16,305	100		95	110	95	107
525F1	17	3				100	16,305	100		97	115	95	113
525F2	29					100	16,485	100		100	115	100	116
625F1	33	4				100	16,305	100		102	127	100	124
625F2	36					100	15,790	100		101	116	99	115
3BFS1	41	1	None	100 (portland blast-furnace slag cement)	None	100	16,855	100		94	102	89	101
3BFS2	19					100	16,665	100		94	107	93	106
4BFS1	52	2				100	16,665	100		92	101	86	100
4BFS2	21					100	16,485	100		96	108	93	105
5BFS1	16	3				100	16,575	100		97	108	92	108
5BFS2	2					100	16,760	100		95	108	92	108
6BFS1	5	4				100	16,855	100		95	108	89	97
6BFS2	37					100	16,215	100		102	107	100	104
335F1	22	1	65 (cement A)	None	35 (fly ash)	100	16,855	100		94	111	93	108
335F2	54					100	16,855	100		87	105	82	105
435F1	46	2				100	16,855	100		90	106	88	103
435F2	48					100	16,760	100		90	111	84	107
535F1	47	3				100	16,395	100		95	94	93	90
535F2	34					100	16,045	100		101	120	96	120
635F1	32	4				100	16,485	100		98	114	97	110
635F2	43					100	15,705	100		101	121	99	118

\* Position in row 1 of exposure rack starting from western end. For example: Prism 30021 is the 10th prism from the western end of row 1.

\*\* See text of Section 39 for outline of curing conditions.

† All percentages are by solid volume of total cementitious material.

†† Satisfactory flexural frequency readings were not obtained on any of these prisms in 1969 due to malfunction of testing equipment.

\* A satisfactory reading was not obtained.

(Revised May 1976)

Table 1-CT (Continued)

Section 39

Prism No.	Position on Rack	Curing Condition	Type II Portland Cement %	Other Cement %	Other Re-placement Material %	Exposure Rack, Row 1							
						633 Cycles 1972		773 Cycles 1973		909 Cycles 1974		1021 Cycles 1975	
						SE	SV <sup>2</sup>	SE	SV <sup>2</sup>	SE	SV <sup>2</sup>	SE	SV <sup>2</sup>
30021	10	1	100 (cement A)	None	None	91	92	99	100	100	100	103	129
30022	49					103	99	103	99	104	99	104	125
40021	14	2				93	94	90	97	87	97	83	115
40022	44					107	97	107	110	100	110	100	123
50021	8	3				108	99	92	110	108	110	105	140
50022	31					111	101	109	109	109	109	109	128
60021	23	4				83	82	83	85	82	85	NR	89
60022	30					109	107	109	110	109	110	108	137
30421	40	1	100 (cement B)	None	None	95	88	90	89	90	89	85	67
30422	20					104	95	103	82	103	82	100	117
40421	15	2				98	93	100	99	97	99	87	111
40422	26					104	96	104	107	104	107	104	36
50421	28	3				98	87	94	79	91	79	84	129
50422	6					100	99	78	102	101	102	101	125
60421	35	4				86	59	85	64	84	64	83	120
60422	11					109	94	108	86	107	86	116	129
325S1	18	1	75 (cement A)	None	25	105	98	107	105	105	105	105	107
325S2	1				(calcined shale)	117	95	92	113	117	113	117	131
425S1	42	2				108	86	106	93	103	93	103	87
425S2	38					101	81	102	106	100	106	101	38
525S1	51	3			25	122	85	95	103	101	103	101	92
525S2	12				(shale)	107	100	113	112	113	112	118	133
625S1	27	4				108	85	97	79	90	79	83	108
625S2	13					116	99	116	108	116	108	111	127
335N1	3	1	65 (cement A)	35 (nat cement)	None	98	93	99	95	96	95	93	102
335N2	24					103	89	100	88	97	88	74	103
435N1	50	2				100	90	106	97	98	97	NR	102
435N2	9					104	92	90	113	111	113	112	125
535N1	55	3				102	33	99	61	98	61	NR	58
535N2	39					99	83	96	82	100	82	97	127
635N1	4	4				98	59	81	47	77	47	70	33
635N2	7					108	99	106	81	104	81	101	113
325F1	53	1	75 (cement A)	None	25	101	75	95	82	95	82	95	100
325F2	45				(fly ash)	107	93	108	93	105	91	110	126
425F1	56	2				108	95	93	95	90	95	NR	107
425F2	25					97	86	108	98	111	98	110	134
525F1	17	3				107	100	110	100	108	100	117	132
525F2	29					111	101	113	105	112	105	113	120
625F1	33	4				106	100	104	107	104	107	100	99
625F2	36					115	92	115	100	118	100	115	43
3BFS1	41	1	None	100	None	92	77	87	75	92	75	87	32
3BFS2	19			(portland)		106	95	106	102	105	102	104	124
4BFS1	52	2		blast-		98	44	90	78	90	78	90	91
4BFS2	21			furnace		101	99	101	98	104	98	104	112
5BFS1	16	3		slag		102	80	99	79	99	79	107	102
5BFS2	2			cement)		96	94	83	94	97	94	NR	105
6BFS1	5	4				94	84	88	84	87	84	77	103
6BFS2	37					100	78	93	100	94	100	91	126
335F1	22	1	65 (cement A)	None	35	105	96	102	92	102	92	103	118
335F2	54				(fly ash)	106	49	105	91	105	91	NR	116
435F1	46	2				103	84	100	93	106	93	109	115
435F2	48					104	91	101	91	104	91	104	91
535F1	47	3				103	99	85	99	84	99	84	122
535F2	34					117	89	122	79	122	79	127	58
635F1	32	4				108	97	106	100	110	100	115	126
635F2	43					120	91	120	103	102	103	107	141

(Issued August 1977)

Table 1-CT (Continued)

Section 39

Exposure Rack, Row 1

Prism No.	Position on Rack	Curing Condition	Type II Portland Cement %	Other Cement %	Other Replacement Material %	1167 Cycles 1976		1244 Cycles 1977	
						%E	%V <sup>2</sup>	%E	%V <sup>2</sup>
30021	10	1	100 (cement A)	None	None	99	99	99	98
30022	49					104	98	101	92
40021	14	2				109	91	105	70
40022	44					93	98	101	68
50021	8	3				102	100	101	96
50022	31					108	102	110	109
60021	23	4				NR*	66	61	78
60022	30					102	105	102	109
30421	40	1	100 (cement B)	None	None	86	85	101	24
30422	20					91	93	95	99
40421	15	2				96	96	88	92
40422	26					95	109	98	84
50421	28	3				84	86	83	Broken
50422	6					98	98	95	102
60421	35	4				71	44	62	Broken
60422	11					113	66	100	89
325S1	18	1	75 (cement A)	None	25	97	75	96	75
325S2	1				(calcined shale)	108	104	106	83
425S1	42	2				119	26	NR	NR
425S2	38					100	89	100	Broken
525S1	51	3			25 (shale)	Broken	61	NR	Broken
525S2	12					116	96	110	108
625S1	27	4				75	NR	88	109
625S2	13					101	96	113	98
335N1	3	1	65 (cement A)	35 (nat cement)	None	110	82	84	72
335N2	24					97	94	90	86
435N1	50	2				108	98	94	79
435N2	9					100	101	102	94
535N1	55	3				128	50	120	Broken
535N2	39					124	NR	118	101
635N1	4	4				Broken		Broken	
635N2	7					109		98	
325F1	53	1	75 (cement A)	None	25	101	81	90	81
325F2	45				(fly ash)	106	97	105	100
425F1	56	2				84	96	80	95
425F2	25					116	99	112	96
525F1	17	3				112	103	104	105
525F2	29					107	100	104	80
625F1	33	4				100	95	97	87
625F2	36					124	107	110	60
3BFS1	41	1	None	100	None	95	NR	69	84
3BFS2	19			(portland blast-furnace slag cement)		96	94	96	93
4BFS1	52	2				110	68	107	59
4BFS2	21					110	92	99	90
5BFS1	16	3				99	72	84	68
5BFS2	2					86	74	78	Broken
6BFS1	5	4				97	41	71	Broken
6BFS2	37					110	73	109	97
335F1	22	1	65 (cement A)	None	35	102	97	101	104
335F2	54				(fly ash)	109	85	102	69
435F1	46	2				92	97	93	93
435F2	48					105	83	94	89
535F1	47	3				79	88	79	94
535F2	34					125	NR	123	97
635F1	32	4				107	91	101	92
635F2	43					110	89	112	69

\* NR means no reading was obtained.

(Sheet 3)

Investigation of Plastic Based Mortar Coatings

In July 1969, eight concrete panels (nominal size 10 by 10 by 3 in.) were installed on the exposure rack at Treat Island. These panels are part of an investigation to determine the field durability of certain plastic based coatings.

The panels were made of air-entrained concrete containing 3/4-in. maximum size natural coarse aggregate, natural sand fine aggregate, and type II portland cement. The concrete in four of the panels had a 28-day compressive strength of 3000 psi, while the concrete in the other four had a 28-day compressive strength of 5000 psi. Each panel (10 by 10 by 3 in.) was formed against a plywood mold, moist-cured for 28 days, and then stored at a relative humidity of 50 percent for seven days (at laboratory temperature). After this 35-day curing period each panel was coated with a 1/8- to 1/4-in.-thick plastic based mortar coating in accordance with the coating manufacturer's specifications. The coated panels were then stored at 50 percent relative humidity (at laboratory temperature) for 28 days and then shipped to Treat Island.

The eight panels installed in July 1969 were coated with a plastic based mortar coating designated PMC-1. Table 1-MBC lists these panels and gives their exposure record along with other pertinent information.

In early November 1969, eight additional concrete panels of the same size were installed on the Treat Island exposure rack. These panels were identical in every respect to the first eight panels except that a different plastic based mortar coating, designated PMC-2, was used. The exposure record and other information about these panels are given in table 2-MBC.

Panels representing two additional plastic based mortar coatings were installed at Treat Island in December 1971. The mortar coatings, designated PMC-3 and PMC-4, represent two new materials. The panels are identical with previous ones exposed. The exposure record and other information are given in Tables 3-MBC and 4-MBC.

(Revised Aug 1974)

Section 40

Table 1-MBC

Investigation of Plastic Based Mortar Coatings

Record of Testing of Concrete Panels

1969- (Installed July 1969)

Panel No.	28-day Compressive Strength of Mixture, psi	Mortar Coating	Exposure Rack, Row 5 (W to E) 1969-1971 Conditions		
			0	153	322
			Cycles 1969	Cycles 1970	Cycles 1971
I-A-1	3000	PMC-1	Sound	Light spalling	Heavy spalling
I-A-2	3000	PMC-1	Sound	Moderate spalling	Heavy spalling
I-A-3	3000	PMC-1	Sound	Moderate spalling	Heavy spalling
I-A-4	3000	PMC-1	Sound	Moderate spalling	Heavy spalling
I-B-1	5000	PMC-1	Sound	Heavy spalling	Heavy spalling
I-B-2	5000	PMC-1	Sound	Heavy spalling	Heavy spalling
I-B-3	5000	PMC-1	Sound	Heavy spalling	Heavy spalling
I-B-4	5000	PMC-1	Sound	Heavy spalling	Heavy spalling

479 Cycles, 1972\*

I-A-1	3000	PMC-1	Mortar coating completely deteriorated
I-A-2	3000	PMC-1	Mortar coating completely deteriorated
I-A-3	3000	PMC-1	Mortar coating completely deteriorated
I-A-4	3000	PMC-1	Mortar coating completely deteriorated
I-B-1	5000	PMC-1	Mortar coating completely deteriorated
I-B-2	5000	PMC-1	Mortar coating completely deteriorated
I-B-3	5000	PMC-1	Mortar coating completely deteriorated
I-B-4	5000	PMC-1	Mortar coating completely deteriorated

\* Monitoring discontinued after 1972 inspection.

(Revised Aug 1974)

Section 40

Table 2-MBC

Investigation of Plastic Based Mortar CoatingsRecord of Testing of Concrete Panels1969- (Installed November 1969)

Panel No.	28-day Compressive Strength of Mixture, psi	Mortar Coating	Exposure Rack, Row 5 (W to E) 1969-1971 Conditions		
			0	153	322
			Cycles 1969	Cycles 1970	Cycles 1971
II-A-1	3000	PMC-2	Sound	Light spalling	Heavy spalling
II-A-2	3000	PMC-2	Sound	Light spalling	Heavy spalling
II-A-3	3000	PMC-2	Sound	Light spalling	Heavy spalling
II-A-4	3000	PMC-2	Sound	Sound	Heavy spalling
II-B-1	5000	PMC-2	Sound	Sound	Heavy spalling
II-B-2	5000	PMC-2	Sound	Sound	Heavy spalling
II-B-3	5000	PMC-2	Sound	Light cracking	Heavy spalling
II-B-4	5000	PMC-2	Sound	Sound	Moderate spalling

479 Cycles, 1972

II-A-1	3000	PMC-2	Mortar coating completely deteriorated
II-A-2	3000	PMC-2	Mortar coating completely deteriorated
II-A-3	3000	PMC-2	Heavy spalling
II-A-4	3000	PMC-2	Heavy spalling
II-B-1	5000	PMC-2	Heavy spalling
II-B-2	5000	PMC-2	Heavy spalling
II-B-3	5000	PMC-2	Heavy spalling
II-B-4	5000	PMC-2	Moderate spalling

619 Cycles, 1973\*

II-A-1	3000	PMC-2	Mortar coating completely deteriorated
II-A-2	3000	PMC-2	Mortar coating completely deteriorated
II-A-3	3000	PMC-2	Mortar coating completely deteriorated
II-A-4	3000	PMC-2	Mortar coating completely deteriorated
II-B-1	5000	PMC-2	Mortar coating completely deteriorated
II-B-2	5000	PMC-2	Mortar coating completely deteriorated
II-B-3	5000	PMC-2	Mortar coating completely deteriorated
II-B-4	5000	PMC-2	Mortar coating completely deteriorated

\* Monitoring discontinued after 1973 inspection.

Table 3-MBC

Investigation of Plastic Based Mortar CoatingsRecord of Testing of Concrete Panels1970- (Installed Dec 1970)

Panel No.	28-day Compressive Strength of Mixture, psi	Mortar Coating	Exposure Rack, Row 5 (W to E) 1970-1972 Conditions		
			0	156	313
			Cycles 1970	Cycles 1971	Cycles 1972
III-A-1	3000	PMC-3	Sound	Light spalling	Light spalling
III-A-2	3000	PMC-3	Sound	Light spalling	Light spalling
III-A-3	3000	PMC-3	Sound	Light spalling	Light spalling
III-A-4	3000	PMC-3	Sound	Light spalling	Light spalling
III-B-1	5000	PMC-3	Sound	Light spalling	Light spalling
III-B-2	5000	PMC-3	Sound	Light spalling	Light spalling
III-B-3	5000	PMC-3	Sound	Light spalling	Light spalling
III-B-4	5000	PMC-3	Sound	Light spalling	Light spalling

453 Cycles, 1973\*

III-A-1	3000	PMC-3	Mortar coating completely deteriorated		
III-A-2	3000	PMC-3	Mortar coating completely deteriorated		
III-A-3	3000	PMC-3	Mortar coating completely deteriorated		
III-A-4	3000	PMC-3	Mortar coating completely deteriorated		
III-B-1	5000	PMC-3	Mortar coating completely deteriorated		
III-B-2	5000	PMC-3	Mortar coating completely deteriorated		
III-B-3	5000	PMC-3	Mortar coating completely deteriorated		
III-B-4	5000	PMC-3	Mortar coating completely deteriorated		

\* Monitoring discontinued after 1973 inspection.

Table 4-MBC

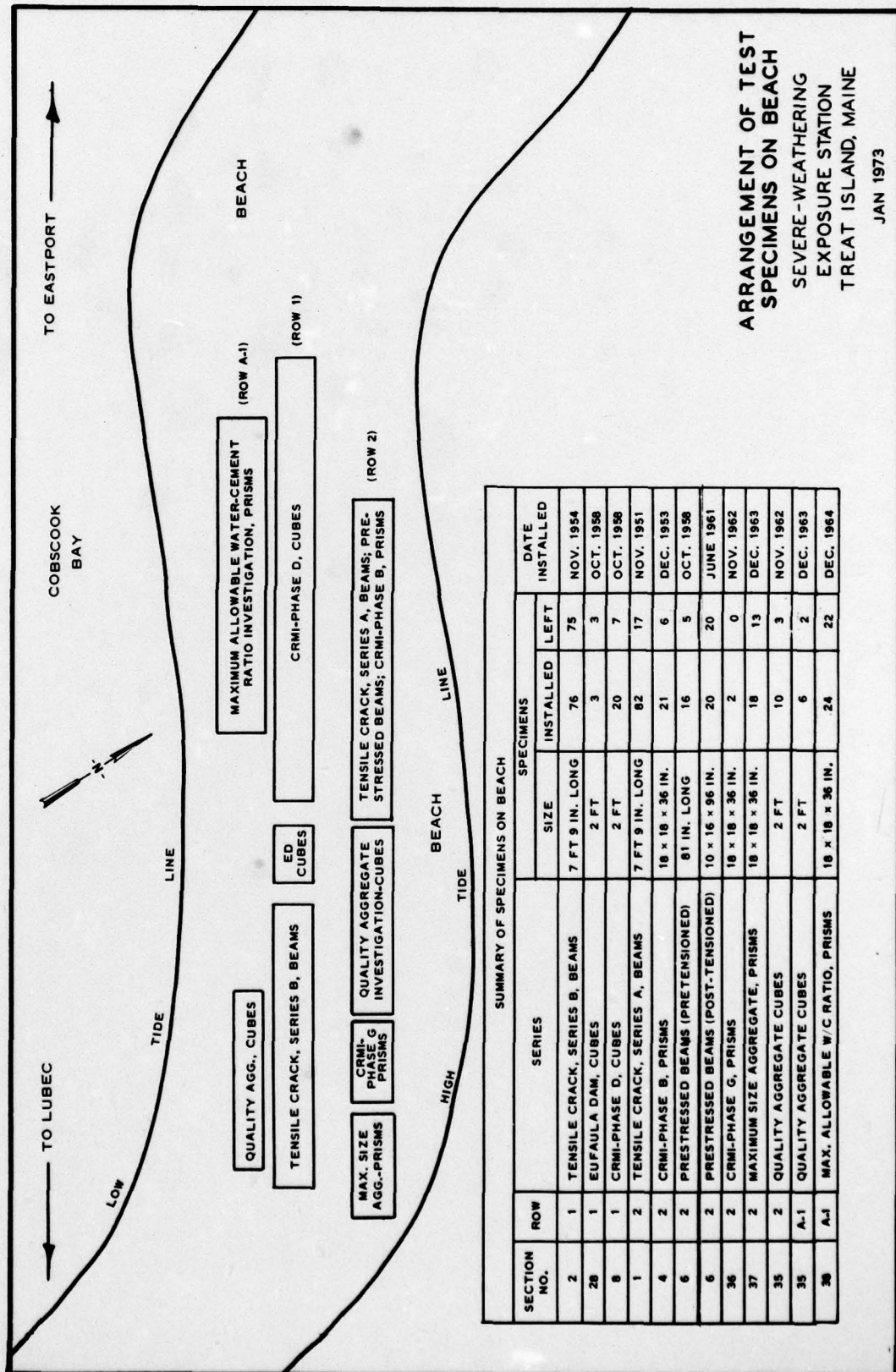
Investigation of Plastic Based Mortar CoatingsRecord of Testing of Concrete Panels1970- (Installed Dec 1970)

Panel No.	28-day Compressive Strength of Mixture, psi	Mortar Coating	Exposure Rack, Row 5 (W to E) 1970-1972 Conditions		
			0	156	313
			Cycles 1970	Cycles 1971	Cycles 1972
IV-A-1	3000	PMC-4	Sound	Light spalling	Light spalling
IV-A-2	3000	PMC-4	Sound	Sound	Light spalling
IV-A-3	3000	PMC-4	Sound	Light spalling	Light spalling
IV-A-4	3000	PMC-4	Sound	Light spalling	Light spalling
IV-B-1	5000	PMC-4	Sound	Sound	Sound
IV-B-2	5000	PMC-4	Sound	Sound	Sound
IV-B-3	5000	PMC-4	Sound	Light spalling	Light spalling
IV-B-4	5000	PMC-4	Sound	Light spalling	Light spalling

453 Cycles, 1973\*

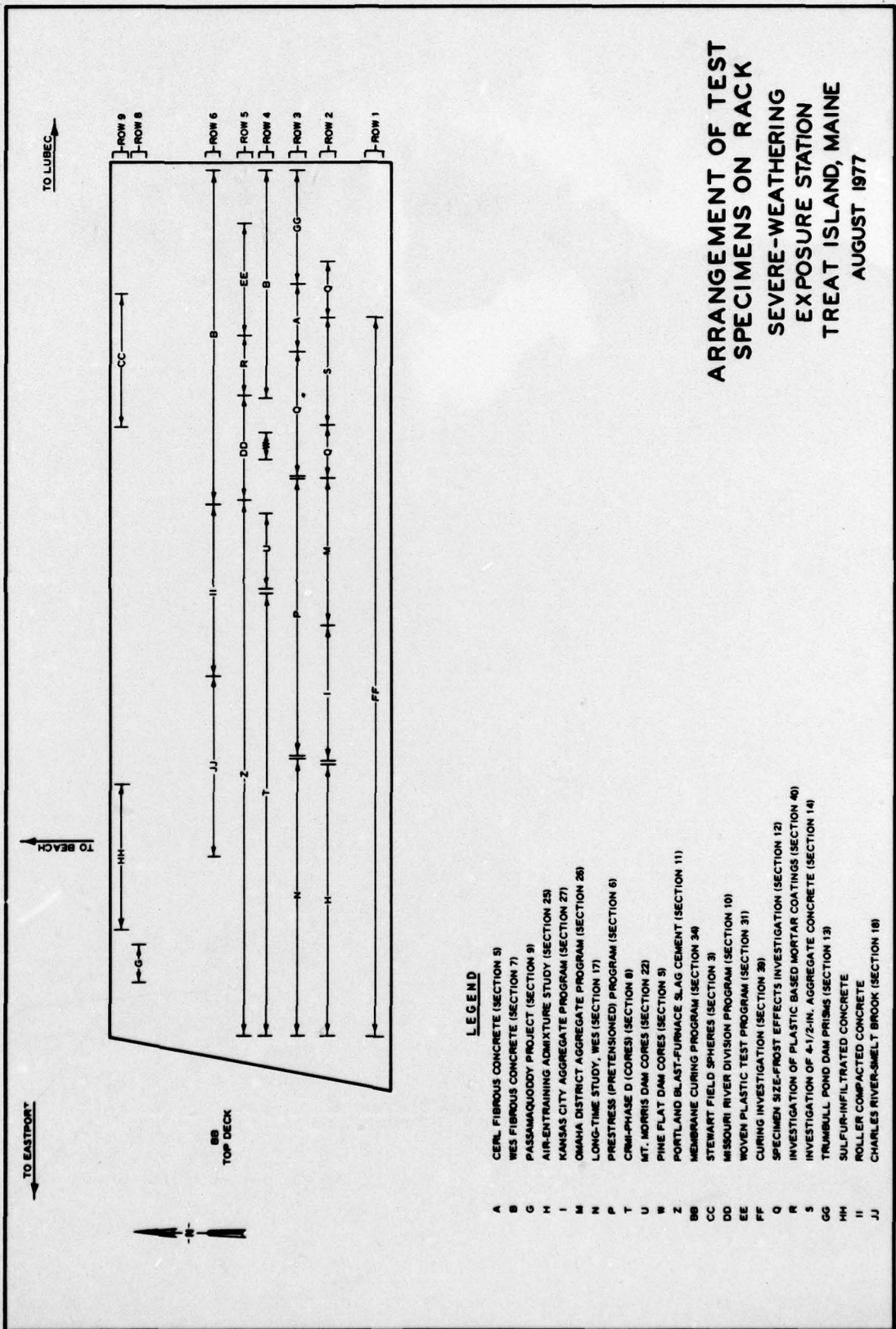
IV-A-1	3000	PMC-4	Mortar coating completely deteriorated
IV-A-2	3000	PMC-4	Mortar coating completely deteriorated
IV-A-3	3000	PMC-4	Mortar coating completely deteriorated
IV-A-4	3000	PMC-4	Mortar coating completely deteriorated
IV-B-1	5000	PMC-4	Mortar coating completely deteriorated
IV-B-2	5000	PMC-4	Mortar coating completely deteriorated
IV-B-3	5000	PMC-4	Mortar coating completely deteriorated
IV-B-4	5000	PMC-4	Mortar coating completely deteriorated

\* Monitoring discontinued after 1973 inspection.

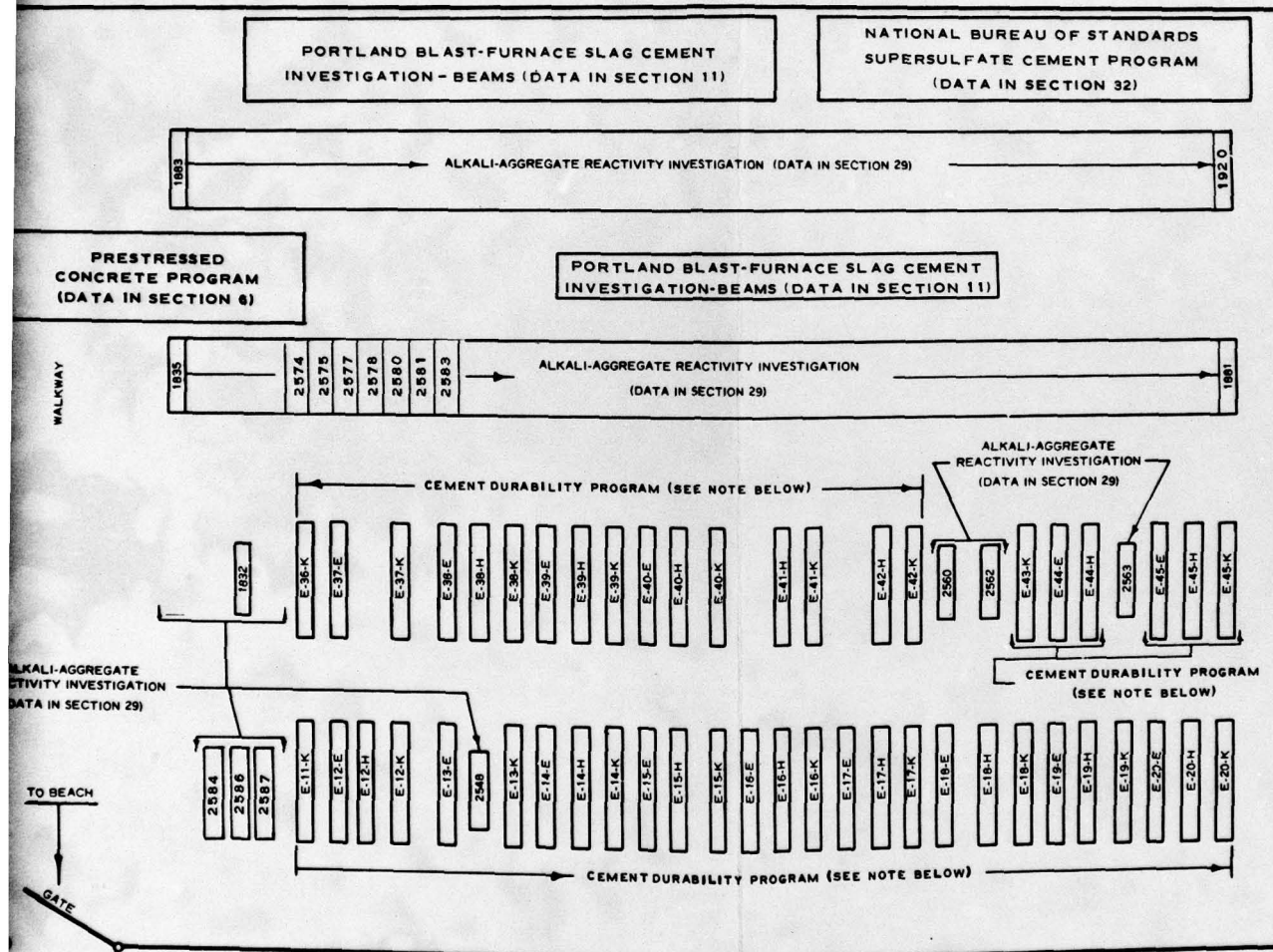
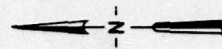


**ARRANGEMENT OF TEST SPECIMENS ON BEACH**  
SEVERE-WEATHERING EXPOSURE STATION  
TREAT ISLAND, MAINE

JAN 1973







ARRANGEMENT OF TEST SPECIMENS  
MILD-WEATHERING EXPOSURE STATION  
ST AUGUSTINE, FLORIDA

(SEE TABLE 2)

JAN. 1972

NOT TO SCALE